Volume 27 JULY, 1943 Number 7

BULLETIN
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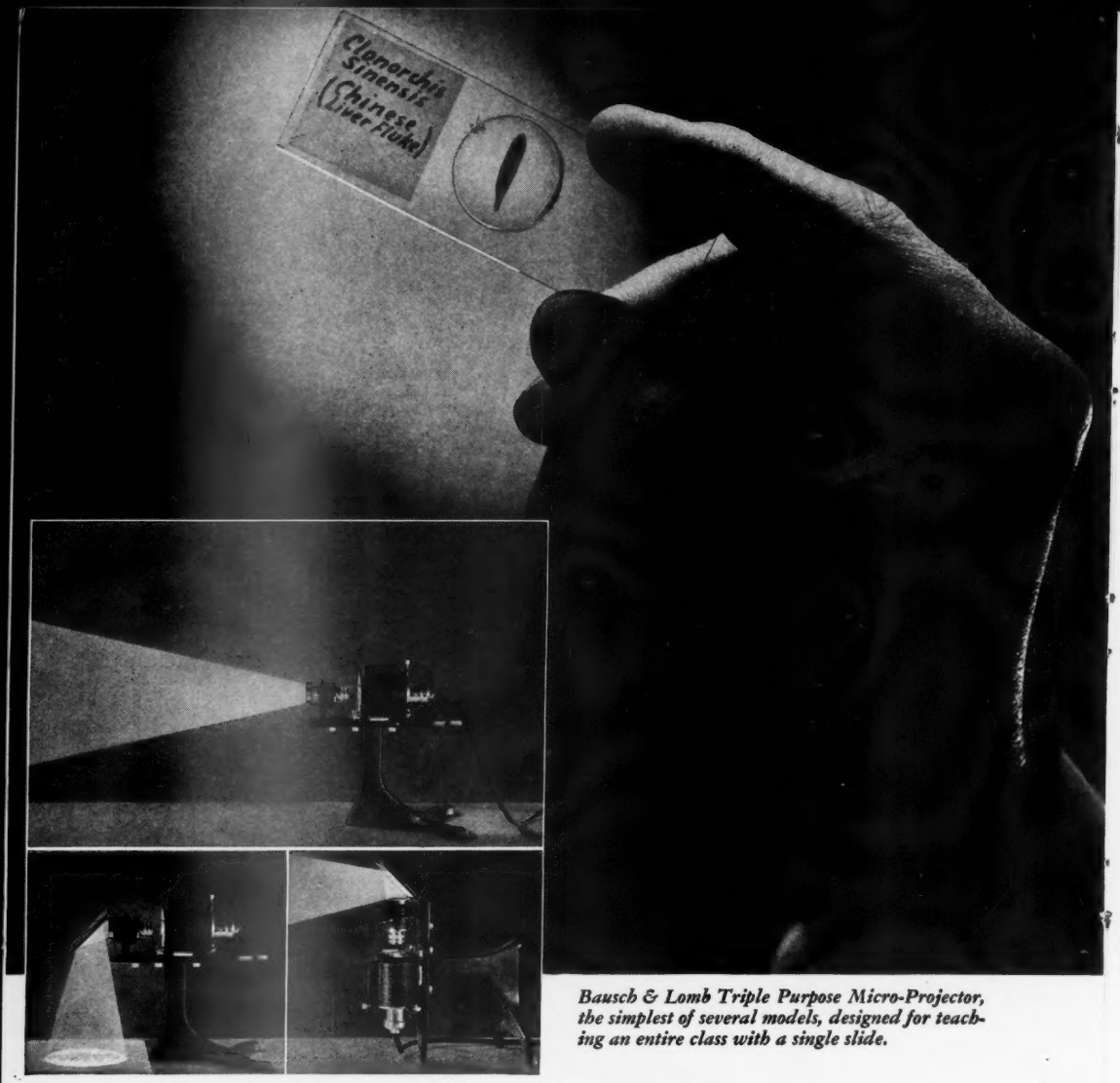

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by

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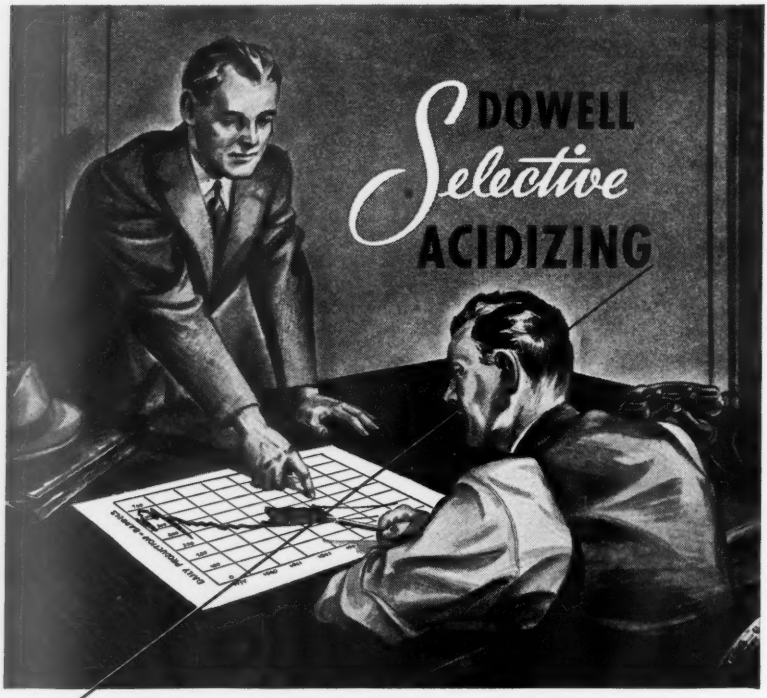

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Volume 27 Number 7

BULLETIN
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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

JULY, 1943

DISCOVERY THINKING[1]

A. I. LEVORSEN[2]
Tulsa, Oklahoma

Every man, woman, and child in the United States had a stake in the oil industry during times of peace, but now that we are at war, the stake is infinitely greater, for, as top-ranking government officials say, "petroleum is one of the most essential of war industries."[3] This stake is expressed in many ways: through ownership in the industry; in utilization of its products as fuel, power or raw materials; in an appreciation of the many taxes paid by the oil industry; and in the applications of petroleum and its products to war. The affairs of the petroleum industry have outgrown the simple business of producing, manufacturing, and selling petroleum and its products; they are now of universal military, economic, social, and political importance. As a matter of fact, the public is in the oil industry and probably here to stay.

Because of this public interest in petroleum, society, in planning and thinking of its future, has the right continually to ask "How long can we depend on a supply of petroleum adequate for our needs?" "What about the future reserves?" "Can we continue to build an economy based on an abundance of raw materials in the form of petroleum and gas?" And we in the oil industry, as the custodians of this national resource, should continually be prepared to give answer so that the time does not come when the public finds that it has been misled; when, instead of scarcity there is plenty; or when, instead of plenty there is scarcity. Much planning—economic, military and political—will be affected by the answer and it becomes a public responsibility that the answer be as accurate and as up-to-date as possible.

In approaching such a problem as this, it is well first to get some idea of its size and proportions. The problem from a national viewpoint is not the same as it

[1] Read before the Association at Fort Worth, April 7, 1943. Manuscript received, April 14, 1943.

[2] Consulting geologist, 221 Woodward Boulevard. Chairman, Association research committee.

[3] Harold L. Ickes, Petroleum Administrator for War, and Paul V. McNutt, Chairman, War Manpower Commission, *Chicago Journal of Commerce* (February 10, 1943), p. 13.

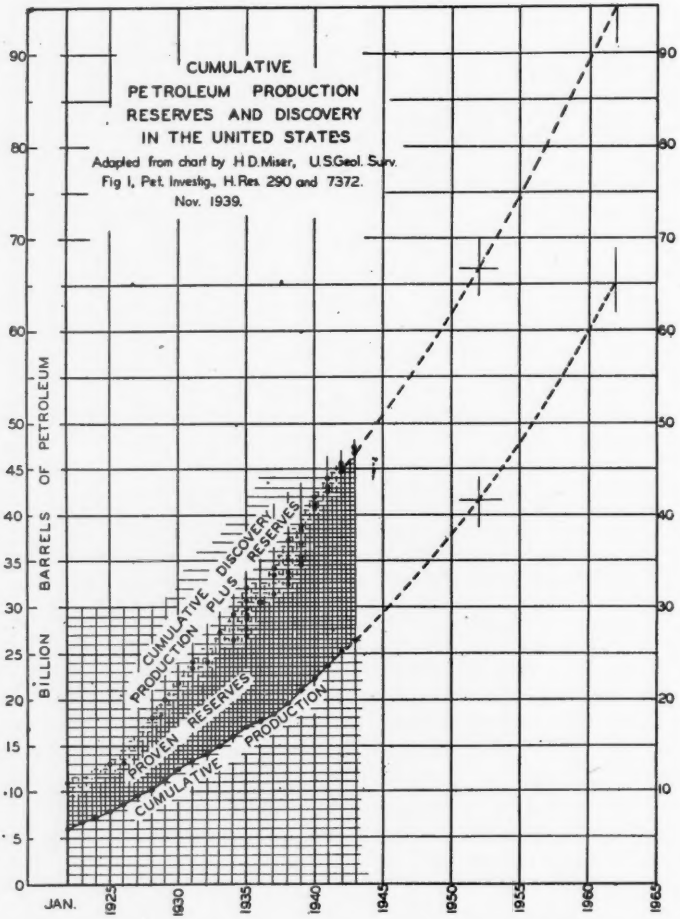

FIG. 1.—Chart showing, through use of cumulative curves, past trends in petroleum production and reserves in United States. When projected into the future, dashed lines indicate magnitude of discovery problem if present trends continue. Upper black dots indicate estimates of reserves by various authorities in different years.

is from the viewpoint of the individual or even that of a major oil company—the individual or company needs are infinitesimal by comparison. Figure 1 is designed to indicate the future needs by the projection of our past record of growing supply and demand. Here we see that during the next 20 years, or by 1963, if we are to maintain the same rate of increase in production as in the last 20 years, and if we are to continue to have as a discovered reserve 13 or 14 times the annual production, it will be necessary to discover the staggering amount of 50 billion barrels of new oil. This is a greater amount than has been discovered by all methods since the beginning of the oil industry 80 years ago. The present trends, when projected into the future, indicate a steadily increasing tempo of discovery, production, and consumption. We are talking about a lot of oil and in the light of our current decline in rates of discovery in the face of steadily increasing war needs, we have something deserving the most serious and careful attention.

Experience has demonstrated that the uses of petroleum have expanded with the expanding supply. When there has been an extra amount of petroleum, industry has developed new uses to take up the surplus. We have recently seen how a local shortage—due it is true to a shortage in transportation, but in effect a shortage in petroleum, nevertheless—quickly caused a shifting to other sources of energy and heat. This may well be the clue as to what will happen at any future time if a shortage of petroleum should develop. Since the supply of petroleum is directly related to discoveries of new oil pools, it is quite obvious that the key to the whole question of future supply rests in the ability of the industry to make the necessary discoveries. Failing to discover new pools, the entire economy dependent on petroleum is affected.

Since no one can know in any exact or even approximate sense what the discoveries of a year, or even a month in advance may be, another problem is to decide what sort of an approach can be made toward some reasonable idea of the amount and location of the future petroleum reserves. It seems to me that the only answer available to us is that the approach must be made through the reason and philosophy which result from past experience and which may be applied to the future. The best we can hope to do is to continue to add to our present small supply of philosophy concerning the relations of petroleum to geology, then to apply all such understanding to our knowledge of geological conditions. From that we may decide whether or not there is reason to believe that there are adequate reserves remaining to be discovered, and also how the discoveries may be made. Our answer will be a function of our philosophy, of our theories, and of our thinking.

This has been most effectively stated by Pratt,[4] in discussing the lack of successful discovery in many of the foreign countries.

[4] Wallace E. Pratt, "Geology in the Petroleum Industry," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 7 (July, 1940), pp. 1212–13.

. . . The suspicion grows that physical conditions within the earth's crust impose fewer and less formidable obstacles to the development of commercial oil fields over much of the land area of the globe than are raised up by our prevailing mental and social climates of opinion. The limitations put upon the discovery of oil on earth to-day are more mental and social than physical. Gold is where you find it, as the old adage has it, but oil must be sought first, at least, in the mind . . .

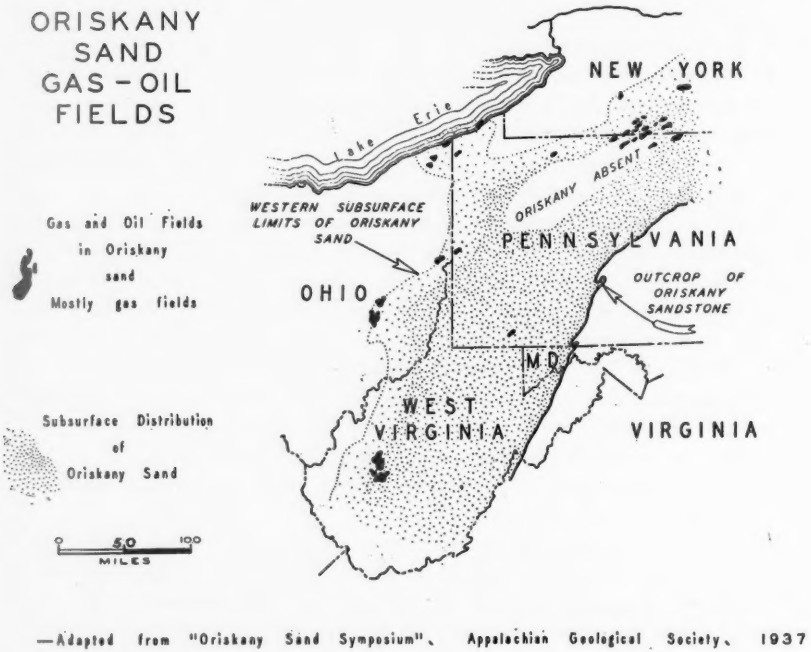

FIG. 2.—Map showing subsurface distribution of Oriskany sand (Lower Devonian). Sand thins out updip northwest. Along this belt of wedging-out of porosity, gas and oil fields producing from Oriskany sand are found. Many fields are in local anticlinal folds.

Much oil has been discovered by mere random drilling, and much will most assuredly be discovered through such means in the future, but the only rational way to make available to society the oil and gas which now lies underground, as the undiscovered reserve, is through the application of scientific methods and reasoning. It is the one approach which offers reproducible results. A correct scientific principle applied to the accumulation and occurrence of oil and gas can be applied repeatedly to Oklahoma, to the United States, or throughout the world—this year, next year, or a hundred years from now. It becomes a foundation upon which we can build indefinitely into the future.

The occurrence and distribution of oil and gas deposits are intimately related to the occurrence and distribution of varying kinds of geological conditions, and because of this relation, the problem of where to search for oil pools and what might be expected to result from this search is fundamentally geological in nature. Within the oil industry, the petroleum geologist is the one to provide the answer about

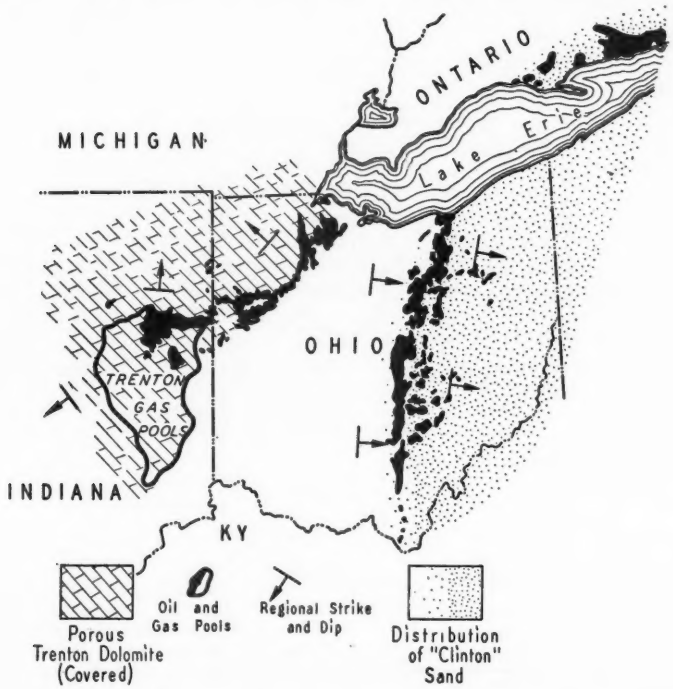

FIG. 3.—Map showing subsurface distribution of Clinton sand (Silurian) with gas and oil fields associated with its thinning-out updip westward, and subsurface distribution of porous dolomite part of Trenton formation (Ordovician) with oil and gas fields associated with updip edge of porosity. Individual pools in both provinces are in part on local structure but mostly associated with local porosity.

the adequacy of our petroleum reserves and about the methods by which they may be discovered. A petroleum geologist is one who is engaged in the interpretation of the relations of the rocks to the occurrence and production of petroleum, whether he began as a paleontologist, a mineralogist, a geophysicist, a geochemist, or as an academic geologist. This problem of the discovery of an adequate oil supply becomes our responsibility to the industry and in turn to the nation. Since the petroleum geologist is the one whose primary purpose is to guide the discovery

effort, it can readily be seen that he occupies a most important post in the national economy—in fact he may well be considered as the keystone in the arch of that part of our future national economy which is dependent on petroleum whether as a source of power, as a fuel, or as a raw material. Truly, geology in all of its history has never reached such a plane of useful application to humanity. The size of the problem gives one real cause to approach an answer in a spirit of deep humility.

FIG. 4.—Pools of Illinois basin region are in region of updip wedging-out of numerous sands and reservoir rocks of Chester or upper Mississippian series. Area now underlain by Chester rocks in Illinois basin is only small segment of area originally part of wedge belt. Chester rocks extended southeast into Arkansas and Oklahoma, east into Appalachian states, and south into Alabama. See A. I. Levorsen, "Pennsylvanian Overlap in United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, No. 2 (February, 1931), pp. 118–48; and "Studies in Paleogeology," *ibid.*, Vol. 17, No. 9 (September, 1933), pp. 1107–32, particularly Fig. 2.

As we have seen, the normal future expansion of the petroleum industry calls for discoveries on a scale which to many is almost, if not, impossible of achievement. Some feel that the decline in discovery rate is because of the approaching exhaustion of our ultimate reserves—that we are scraping the bottom of the barrel, in other words. If this be true the situation is indeed serious. On the other hand the discovery decline may be due to an insufficient discovery effort, in which case something can be done about it.

The first part of what follows is intended as a contribution to our foundation of geological principles which apply to the search for new reserves in the form of new oil provinces. At best it can show only a few aspects of an infinitely large and broad subject—but a subject to which we must give continual attention if we are to utilize and apply the ever-increasing mass of new data being discovered daily throughout the oil areas. Principles, without data on which to apply them,

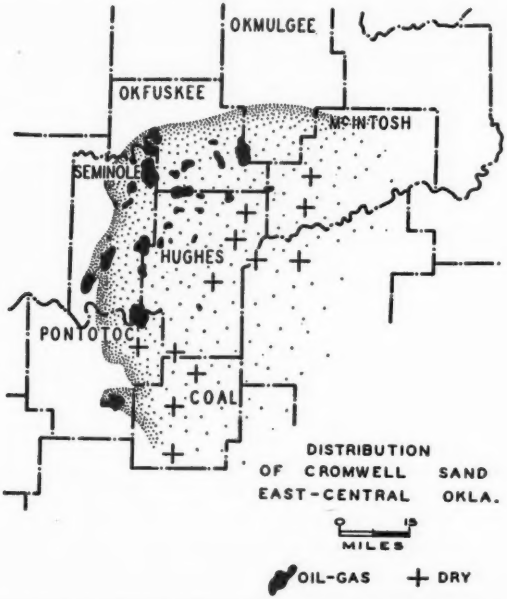

FIG. 5.—Map showing subsurface distribution of Cromwell sand (Pennsylvanian) in east-central Oklahoma. Oil and gas fields, most of them on local anticlines, shown in black; crosses mark equally good or better anticlines which are dry in same formation. Association of oil fields with updip wedging-out of sand is evident.

are of academic interest only, but data without principles by which they might be applied, are useless, costly, and wasteful.

The second part is concerned with some ideas for improving the discovery effort from a strictly geological viewpoint.

UNDISCOVERED RESERVES

Whether the declining discovery is the result of lack of oil to be discovered or lack of effort, there is one factor which enters into the over-all problem and that is, that from a national viewpoint we are too often thinking in too small terms. By far the greatest part of our effort is in searching for extensions to pools already discovered, in searching for deeper sands, and in working and reworking progressively

smaller and smaller areas within the developed provinces. We finally get to think almost exclusively in terms of individual oil fields, when we should be thinking in terms of new oil provinces; in discoveries of millions of barrels, when we should be thinking in terms of billions of barrels; and in acres of new production when we should be thinking in square miles. If you agree that our work is essential to the

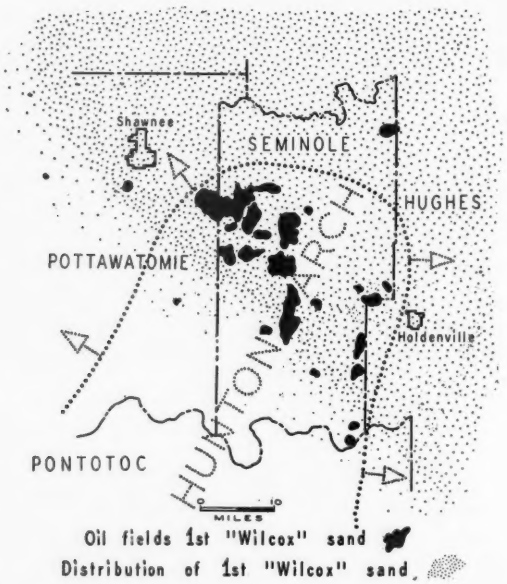

FIG. 6.—First "Wilcox" sand (Ordovician) grades out into dolomite and limestone toward the southwest. Hunton arch crosses edge of porosity as it pitches northeast, and in area where arch crosses wedging-out of sand are found rich pools of Seminole district in Oklahoma. Individual pools are localized by upfolds and local deformation, and province is localized by combination of favorable stratigraphy and regional arching.

future oil supply of the nation, it means that we must turn an increasing part of our thinking into terms of not one but many wholly new oil provinces. It means that we must attempt to think in terms of a steady procession of major oil discoveries into the future. It means that we must think in terms of "big" geology so that we may be assured of "big" results.

In order to reduce this discussion to more concrete terms and to everyday experience, two types of geological concepts or principles are presented to show the kind and the scale of thinking that seems to be called for, in an attempt to formulate a better idea of the nature and the extent of the undiscovered reserves of petroleum in the United States. The layman may say, with a wave of his hand, "There are plenty of reserves, we have always found enough, why worry?", but

we, who are technically trained, must attempt at least to put the answer into terms which can be justified by geological reasoning based on experience and applied to known geological conditions.

The first of these principles has to do with updip wedge belts of porosity in reservoir rocks and the second has to do with the layers of geology which are sepa-

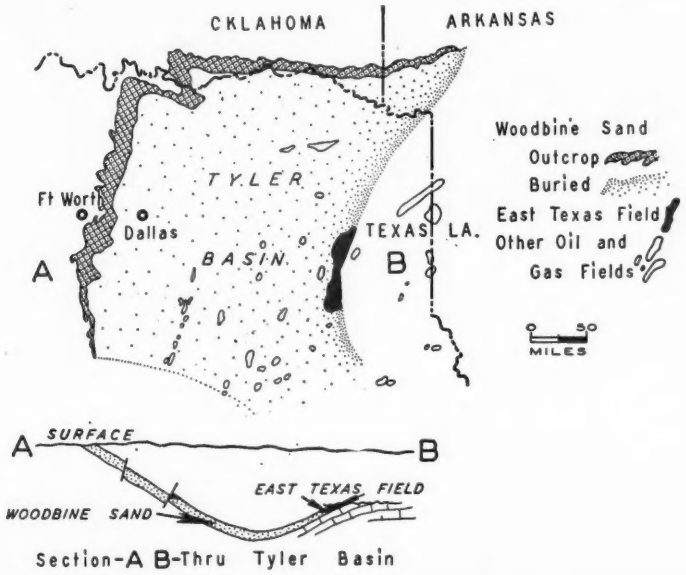

FIG. 7.—Map showing outcrop and subsurface distribution of Woodbine sand (Upper Cretaceous) in northeastern Texas, with East Texas oil field located along eastern, updip wedge edge of porosity. In this case, wedge edge is result of uplift and truncation of Woodbine sand with subsequent overlap of younger formations.

rated by unconformities. They may be considered as principles bearing on the occurrence of oil provinces, both discovered and undiscovered, and it is hoped that an understanding of them will enlarge and clarify your concepts of the occurrence of oil as they have mine.

WEDGE BELTS OF POROSITY

From Pennsylvania to California and from the Ordovician to the Tertiary, we find that oil province after oil province is located in close association with the updip wedging-out of the porosity in the reservoir rock. This association is not coincidental or occasional, as will be seen from the familiar examples which follow, but is a principle which is fundamental to many or probably most of the oil provinces of the United States. The implications of such a philosophy are far-reaching.

Beginning in the eastern United States and moving over the country to California, we find many examples of this relationship and those that follow are selected to show some of the many variations in geological conditions in which the principle is expressed.

These wedge belts of porosity are only a part of those that can be shown to be related to the present distribution of oil and gas pools. Other familiar examples

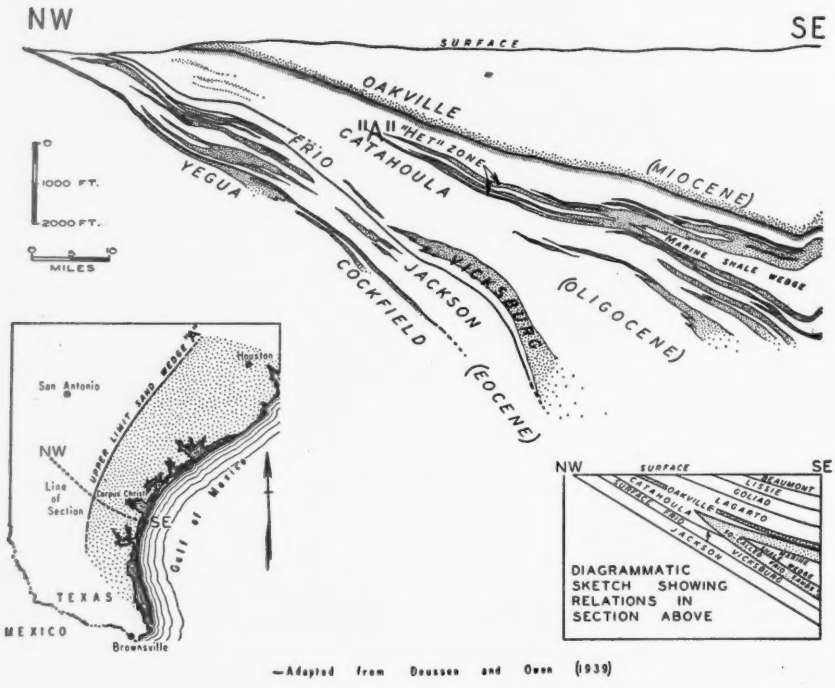

FIG. 8.—Characteristic section along Gulf Coast showing updip wedging-out of most producing sands.

are the Appalachian fields in the Mississippian and Devonian sands; the "Corniferous" production flanking the Cincinnati arch in Kentucky; the Simpson, Bartlesville, and Burbank sand production of northeastern Oklahoma; many of the pools of north-central Texas producing from sands of Pennsylvanian age; many pools in the Laredo district of South Texas; the Lower Cretaceous production of Arkansas and Louisiana; and pools in the Santa Maria Valley, the Eocene and Miocene production in the vicinity of the Coalinga nose, and much of the "East Side" production of the San Joaquin Valley in California. The areas mentioned are shown in Figure 12.

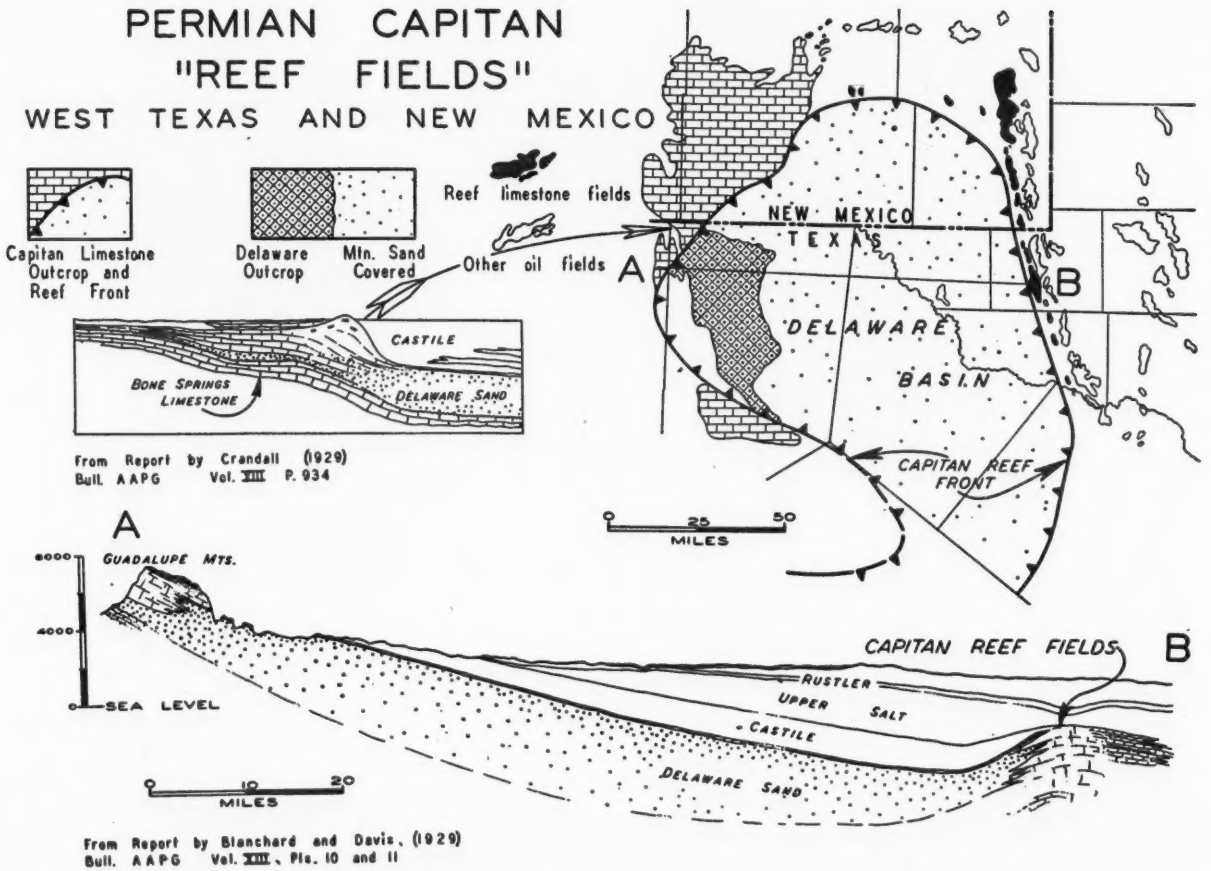

FIG. 9.—Map showing "reef fields" of West Texas and southeastern New Mexico. Fields shown in black are located along fringing reef limestone which occurs along edge of Delaware sandstone (Permian). Porous Delaware sand grades into, and is replaced by, porous reef limestone which in turn becomes dense and non-porous eastward. This edge of porosity marks eastern edge of fields in this province. Individual pools are on local folds which occur along reef front.

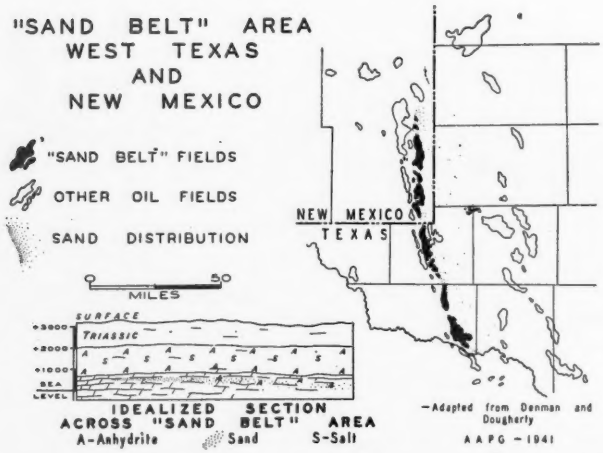

FIG. 10.—Sand Belt pools of West Texas are located along western edge of sand belt in upper part of Permian limestone on back or lagoonal side of fringing reefs.

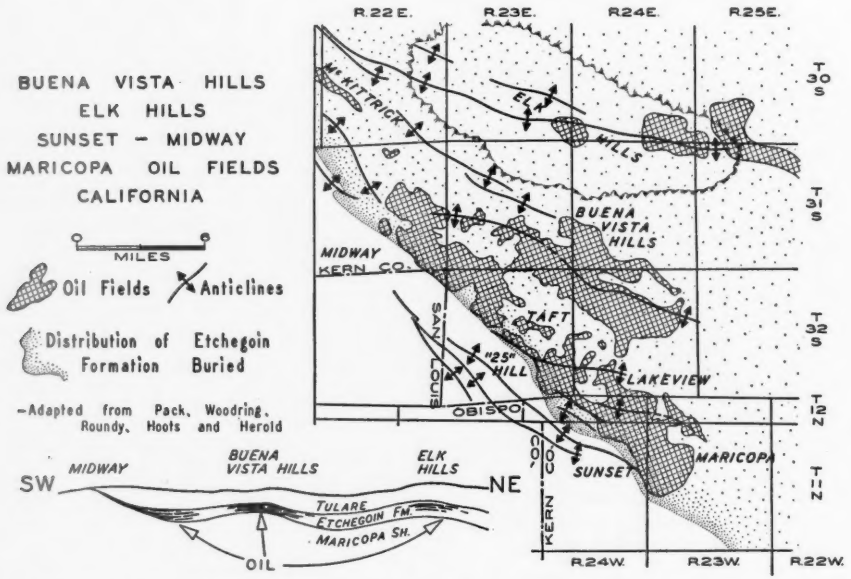

FIG. 11.—Production in Midway-Sunset-Buena Vista province in California occurs in vicinity of updip wedge edge of Etchegoin formation (Pliocene). Sands go out southwest where they are buttressed against rising underlying Maricopa shales along edge of depositional basin in Etchegoin time. Individual pools are associated with local folding and with variable sand conditions.

The origin of a porosity wedge seems to be of less importance than the fact that there is a porosity wedge present. Thus some wedges are the result of a lateral change of facies from sand to shale; others a change from porous limestone or dolomite to non-porous limestone or dolomite; while others are the result of uplifts, truncation, and overlap. The physical presence of an updip wedging-out of porosity, irrespective of origin, seems to be the important factor rather than the nature of its origin.

If we grant the fact that many or even most oil provinces are associated with the wedge edge of porosity of the reservoir rock, whether the accumulation is in the form of single large oil fields, such as the East Texas field, or is in a number of separate pools, each in a local structural trap yet grouped in the vicinity of the edge of porosity, then the question "Why is this the fact?" may well be asked. Three possible explanations are the following.

1. Wedge belts of porosity may be favorable areas of origin of oil for some unknown reason. Such an explanation may readily account for oil located in wedge belts which are the result of primary environmental conditions such as shore lines, sand bars, or areas of facies change, but it is more difficult to see how this would apply to those wedge belts which are due to secondary conditions, such as uplift, erosion and later overlap.

2. Another explanation is that within the wedge belts of porosity, pressure gradient factors are set up which may be instrumental in extracting the oil and gas from the surrounding shales, limestones, and other possible oil sources. In the regional history of almost any reservoir rock, from the time of its deposition to the present, it has experienced many effects of uplift, faulting, tilting, burial, erosion, or in other terms, the pressures within it, whether hydrostatic pressures or rock pressures, have fluctuated almost as a bellows due to its geologic history, diastrophism, and temperature variations. The wedge edge, because it is effectively sealed in one direction, offers resistance to these pressure changes, and the operation and effect of pressures in such areas may be different from what they are in the center of the basin where circulation is free and there is relief from pressure in all directions. There may then result, in the vicinity of the wedge edge, a suction effect on the surrounding rocks when the pressures are lowered in the neighboring regions due to erosion, lowering of hydrostatic head, or diastrophism. This suction effect may "pull" the hydrocarbons out of the surrounding formations and they would thus replace the water which was "pulled" to areas of lower pressures deeper in the basin.

3. The third explanation is that wedge belts of porosity become favorable areas for the accumulation of oil which may have had its origin elsewhere. It depends on the acceptance of the theory of the free migration of oil and gas. Briefly, a wedge belt of porosity is such a favorable area of accumulation because it is the oldest trap in the reservoir rock, commonly being contemporaneous with the reservoir rock in origin. This means then that it is the trap which has the longest period of time in which to accumulate whatever oil and gas are in the reservoir

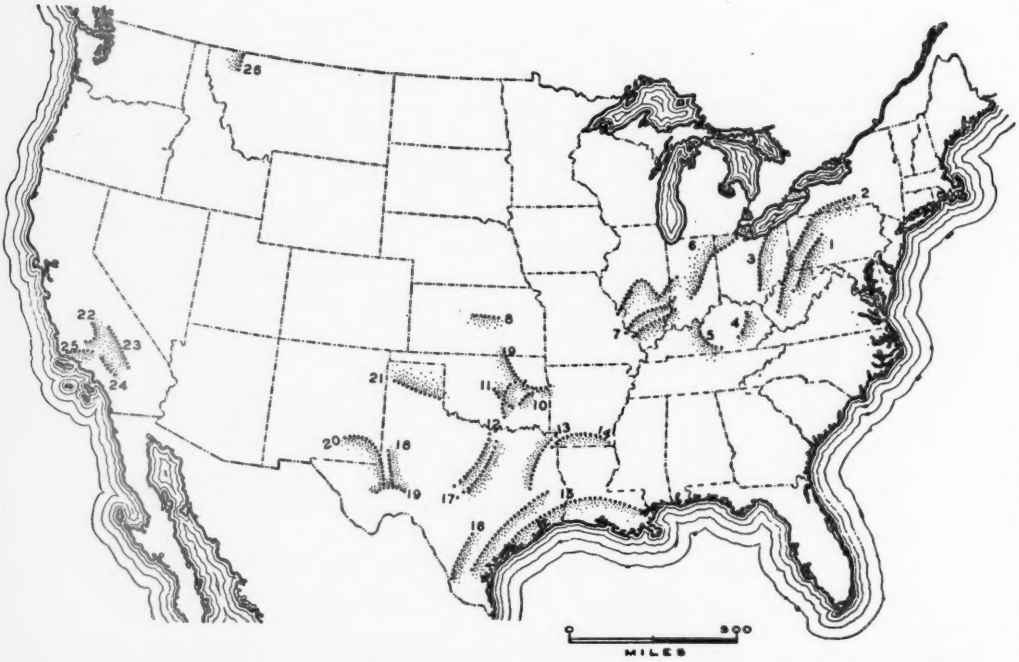

FIG. 12.—Outline map of United States showing some of the petroleum provinces which have in their early history an up-dip wedging-out of porosity in reservoir rock.

1. Numerous lenticular sands, wedging out westward in Mississippian and Devonian of Appalachian region.
2. Oriskany sand as shown in Figure 2.
3. Clinton sand as shown in Figure 3.
4. "Corniferous" province in eastern Kentucky.
5. "Corniferous" production in central Kentucky.
6. Trenton province shown in Figure 3.
7. Several sand wedges of Chester series of upper Mississippian age shown in Figure 4. In addition there are many sand-wedge belts in overlying Pennsylvanian rocks, particularly in old Illinois producing area on LaSalle anticline.
8. Hunton of central Kansas.
9. Simpson sands which wedge out due to overlap of Mississippian rocks around southwest side of Ozark uplift. See also Figure 18.
10. Pennsylvanian "Dutcher" sands of east-central Oklahoma.
11. "First Wilcox" sand of Seminole district. See also Figure 6.
12. Cromwell sand of east-central Oklahoma. See also Figure 5.
13. Woodbine sand of East Texas. See also Figure 7.
14. Lower Cretaceous and Jurassic wedge of southern Arkansas shown also in Figure 21.
15. Productive sands of Texas and Louisiana Gulf Coast shown in Figure 8.
16. Government Wells and other Tertiary sands of southwestern Texas.
17. Strawn sands of eastern Bend arch of north-central Texas. See also Figure 19.
18. "Sand Belt" province of West Texas shown in Figure 10.
19. Part of the Ordovician province of West Texas.
20. Reef limestone province of West Texas. See also Figure 9.
21. Panhandle province along north flank of Amarillo buried granite ridge.
22. East Coalinga-Kettleman province of San Joaquin Valley of California.
23. "East Side" province of San Joaquin Valley of California.
24. Midway-Sunset province of California shown also in Figure 11.
25. Santa Maria province of California.
26. Cutbank area of northwestern Montana.

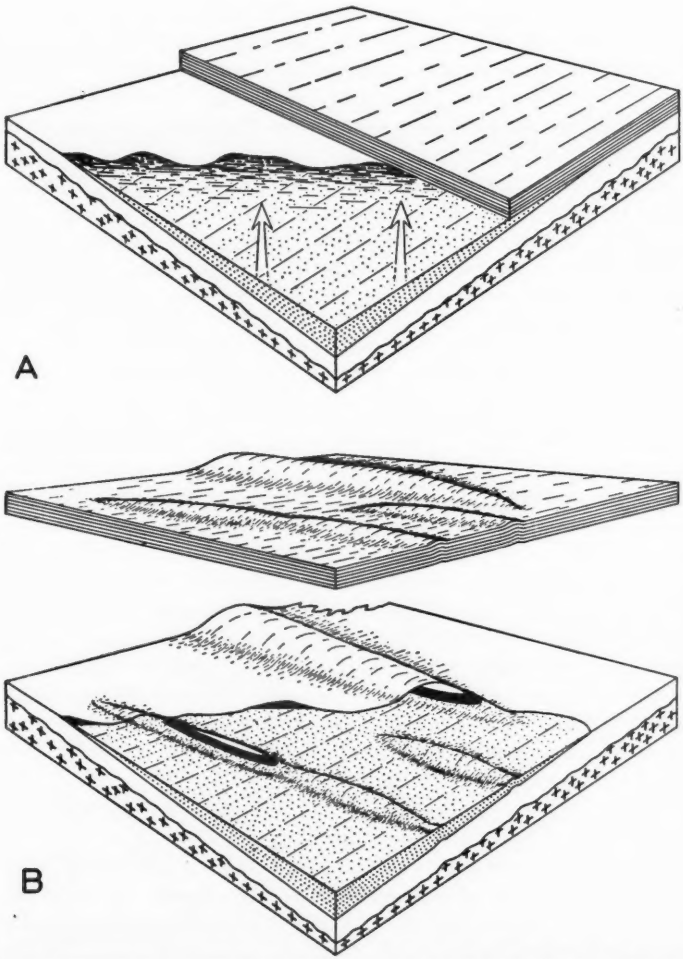

FIG. 13.—Preferred explanation of association of oil and gas pools with updip wedge belts of porosity in reservoir rock. *A* shows overlap of wedge belt of porosity by impermeable cover and movement into wedge-edge area of whatever oil and gas are in reservoir rock under laws of anticlinal or updip accumulation. Subsequently, area is folded, as in *B*, and oil and gas in vicinity of edge become relocalized into traps, some structural and some irregularities in local porosity. Folds too far from edge remain dry or non-commercial since oil had by-passed these areas in its primary movement into wedge-belt area. See also A. I. Levorsen, "Studies in Paleogeology," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, No. 9 (September, 1933), p. 1118.

rock. Since wedge belts are commonly regional in extent the oil that has accumulated in them is on a regional scale, and, in the later folding and deformation in which local and lesser traps are formed, the primary regional accumulation is relocalized into many lesser pools and the area then becomes known as an oil province.

It is the explanation which best seems to account for the relation of many oil provinces to a wedge belt of porosity in the reservoir rock. It may, however, be combined with the other two explanations, to account fully for the relationship in some examples. The principle is illustrated in Figure 13.

As a test of the importance of the time of trap formation in the accumulation history of an oil field, two examples of a negative nature are given. They may be considered as a test "in reverse" of the principle of the close association of updip wedge belts of reservoir porosity with oil provinces.

(1) UPPER CRETACEOUS OF ROCKY MOUNTAIN REGION

Theoretically, the Dakota group of sandstones at the base of the Upper Cretaceous of the Rocky Mountain region should be one of the most prolific oil- and gas-producing formations of the United States. It consists of relatively thick sands covering large areas and underlain and overlain by thick shales, many of which are dark in color and should satisfy the most skeptical geologist as a good source for petroleum. Yet, with scores of large closed anticlines tested, the result is most disappointing and the Dakota group now stands near the bottom of favorable prospective producing formations in the minds of most geologists. Why is this?

It may be due to the absence of any primary oil formation within the sandstone or within the neighboring shales. This would be contrary to the apparently favorable environment, which is nearly everywhere present, of thick dark shales above and commonly below the Dakota horizon. Moreover, there are small pools and numerous showings of oil in the sand, which indicate that conditions were not totally unfavorable for the generation of oil in it.

Another explanation for the general lack of commercial production is in the geologic history and in the absence of the wedge belts of porosity which seem to be so common in more prolific provinces. The sequence is illustrated in Figure 14.

The upper diagram, *A*, shows an idealized section across the Rocky Mountain region at the end of Cretaceous time. The Dakota formation is in the form of a great geosyncline rising from a depth of 14,000 feet near the center of the basin to less than 4,000 feet around the edges. Any oil or gas in the Dakota formation at that time would be expected to move outward and up the dip in the direction of the arrows, in accordance with the anticlinal or structural accumulation of oil and gas. Later, during the Laramide revolution, large anticlines and domes were formed at many places in the region, as shown in *B*, and any oil then remaining in the Dakota sands would be expected to be concentrated in the tops of these structures. The Big Horns, the main ranges of central Colorado, and the Zuni area of New Mexico are typical of the folds formed during this time.

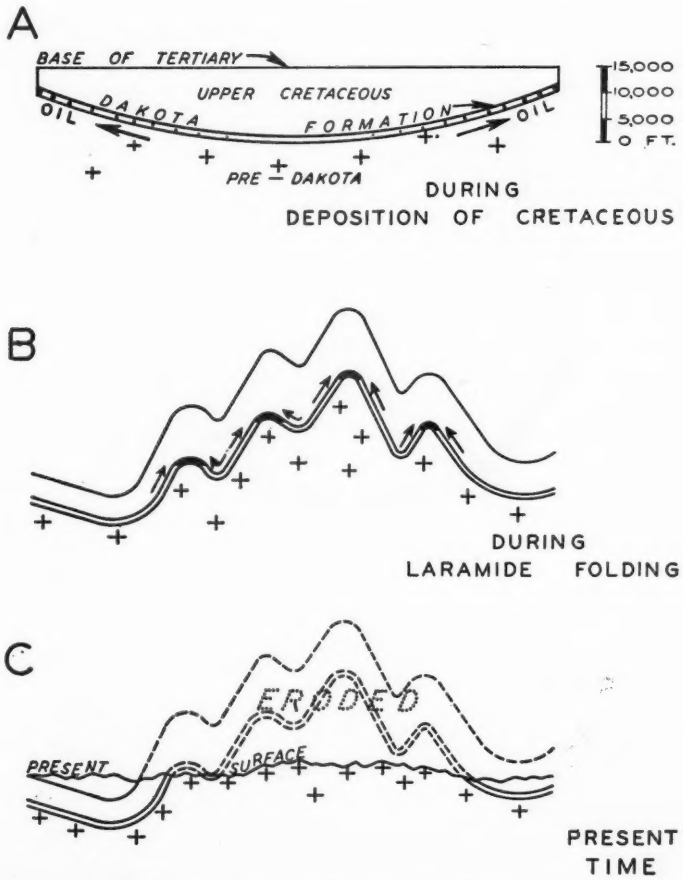

FIG. 14.—Idealized sections across Upper Cretaceous of Rocky Mountain region. *A* shows thinning of Cretaceous rocks from 14,000 feet near center ot basin to less than 4,000 feet along edges. Any oil in Dakota sands during end of Cretaceous time would be expected to move updip toward edges.

B shows condition during and after Laramide period of folding. Any oil remaining in Dakota sands would now be expected to accumulate in tops of large anticlines which were forming.

C shows present conditions, with oil fields eroded during post-Laramide erosion period which exposed granite cores in many areas of Rocky Mountains.

Thus, oil had such excellent opportunities to escape that very few remaining folds in Dakota sand are found to be commercially productive.

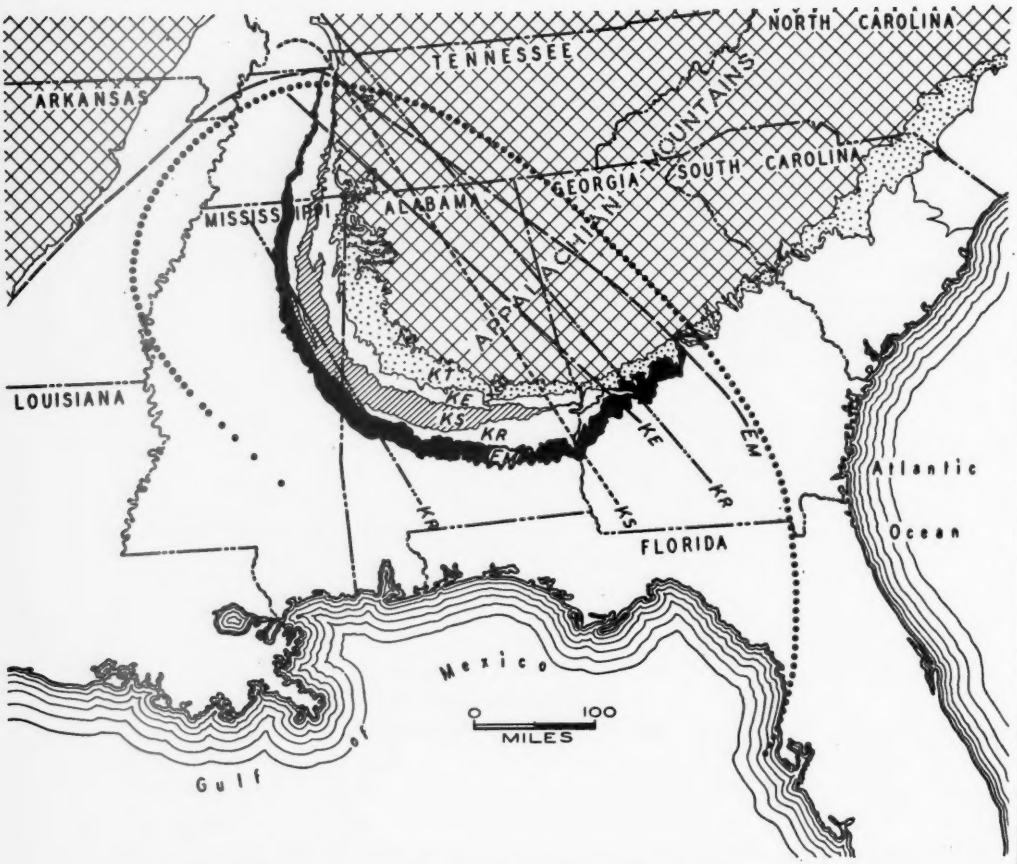

FIG. 15.—Southeastern states, showing present distribution of rocks at surface. EM is Midway formation (Tertiary) and cross-hatched area is basement or pre-Cretaceous complex. Intervening formations are Cretaceous rocks which wedge out north and east. Lines KE (Eutaw), KR(Ripley), KS (Selma), EM (Midway) connect points on northwest and on southeast of like facies. Dotted line marks approximate edge of Tuscaloosa sand.

Subsequently, as indicated in *C*, the high parts of the Rocky Mountain region were eroded away, and with the erosion went whatever oil and gas pools had accumulated during the preceding period. The favorable structures remaining are the lesser ones and relatively small compared with those that were removed. A reason for their generally poor oil showing may be that the region experienced two periods when any oil in the Dakota sands probably escaped, leaving only small remnants of the original oil and gas content. In this connection it is interesting to note that most of the production from the Rocky Mountain structures comes from sands such as the Frontier, Wall Creek, Muddy, Tensleep, and Sundance which wedge out and are regionally lenticular.

(2) UPPER CRETACEOUS OF SOUTHEASTERN UNITED STATES

Another example of the importance of updip wedge belts of porosity, but "in reverse," is in the thick sands of the Eutaw and Tuscaloosa formations in the region south and west of the plunging Appalachian Mountains in Mississippi, Alabama, and Florida. The sequence is illustrated in Figure 15 and Figures 16–A, 16–B, and 16–C.

In this area, the evidence from the areal maps is strongly suggestive of a facies change within the Cretaceous rocks from northeast to southwest. The straight lines in Figure 15 connect points along the outcrop of similar facies or stratigraphic relations. These lines connecting points of like stratigraphy strike northwest and southeast as do also the isopach contours on the total thickness of the Cretaceous rocks where buried in Mississippi and Alabama. The wedging-out of the Cretaceous, north and east along the outcrop is evidence of the conditions which prevailed on the northeast before the Appalachian arching occurred.

The sequence of events is indicated in Figure 16–A, which shows the extent of the Tuscaloosa-Eutaw sands at the time they were overlapped by the overlying Ripley and Midway formations. This edge is an updip wedge edge of porosity, probably largely a shoreline deposit although in part the result of truncation and overlap. Any oil and gas in these porous sands at that time would be expected to move toward the structurally higher edges as shown by the arrows.

Later the region was arched, as shown by the open arrows in Figure 16–B, in the area which is now the southern end of the Appalachians, in northern Louisiana, and in the Ocala, Florida, region. Oil and gas previously concentrated along the wedge belt would now be expected to move along the edge toward the regions of higher structure (hatched) as shown by the solid arrows.

A still later stage was the erosion of the uplifted, arched Appalachian Mountain region with the removal of any oil and gas that may have accumulated there during the arching period. The other areas of possible accumulation are unexplored with the exception of the Tinsley and Pickens pools of Mississippi, which lie within one of the areas of accumulation shown in Figure 16–B.

A sequence of events such as outlined may explain the absence of oil and gas in the eastern Mississippi and southern Alabama region in the structures where

FIG. 16-A.—Map showing area (stippled) underlain by Tuscaloosa and Eutaw sands (Cretaceous). Edge on north and east is due to primary lateral gradation during deposition; edge on west is result of uplift, truncation, and overlap. Any oil in these porous formations, under law of anticlinal or updip accumulation, would be expected to move toward higher sides of basin and become lodged along belt of wedging porosity.

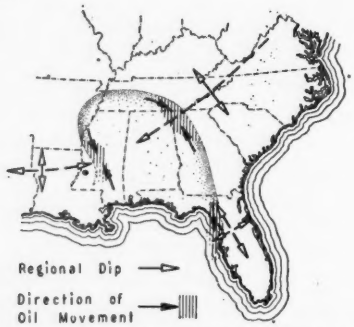

FIG. 16-B.—Later arching of Appalachian Mountain region, Ocala dome in Florida, and arching across northern Louisiana caused general relocalization of oil already accumulated along wedge belt into hatched areas.

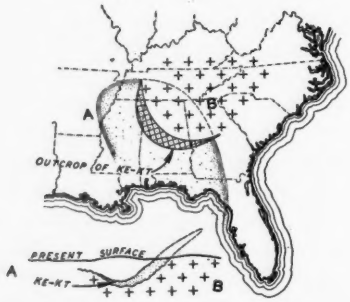

FIG. 16-C.—Erosion of Appalachian arch removed large area of possible accumulation shown in Figure 16-B, located in the vicinity of common state corner of Tennessee, Alabama, and Georgia. Production at Tinsley and Pickens is in region of primary accumulation shown in Figure 16-B.

the Tuscaloosa and Eutaw sand sections have been tested. Whatever oil and gas there ever was in these formations had a chance to escape or by-pass this area before the local folds were formed; thus, the dry structures may be explained by the poor timing of the local folding. Other reservoir rocks of this area may not necessarily be dry since their geologic history may be quite different.

APPLICATION

The application of the principle of wedge belts is simple. If you accept in your thinking an updip wedge edge of porosity in the reservoir rock, whatever the cause, as a fundamental prerequisite to the formation of many or most oil provinces, then you have *immediately* expanded your concept of the undiscovered petroleum reserves of the United States almost without limit. This is because there are thousands of miles of buried, updip, wedge belts of porosity in rocks which are known to produce oil and gas elsewhere, but are to-day only partly explored or completely unexplored. A wedge belt may be called the clue to a province whereas a local fold is the clue to a pool.

Figure 17 shows more than 10,000 miles of such wedge belts remaining to be explored. Fundamentally, they represent the same type of geology which has in the past produced half a billion barrels of oil in the dolomite wedge belt of the Trenton formation of Indiana and Ohio; the same kind of geology which has and will produce 4 billion or more barrels of oil in the 60-mile porosity wedge known as the East Texas field; or which has produced more than a billion barrels of oil along the wedge known as the Midway-Sunset district of California. The evidence for these unexplored wedges is almost entirely in the geologic literature and they are each well known to most geologists. In some places the evidence is largely the result of surface mapping, in others it is the result of a few test wells, and in still others it is the result of various combinations of well known surface and subsurface data. If the confidential data in the hands of the oil companies were available, it is probable that as many more miles of unexplored wedge belts of porosity would be known as are known to-day. If to that is added the new wedge belts of porosity which will most certainly be discovered in the exploration of those wedges now known, the ultimate number of miles which remain to be explored should be sufficient to satisfy the most pessimistic of geologists for many years.

LAYERS OF GEOLOGY

A second principle of geology which has a wide application to petroleum geology is the concept of successive layers of geology in the earth, each separated by an unconformity. They are present in most of the sedimentary regions of the United States and will probably be found to prevail the world over. The discovery of these layers of geology is generally the result of drilling, and many discoveries of oil have been contemporaneous with discoveries of totally unsuspected geology as well. In a few of the well developed oil areas, a rather complete understanding of these layers can be obtained; in most other regions, these layers will probably be

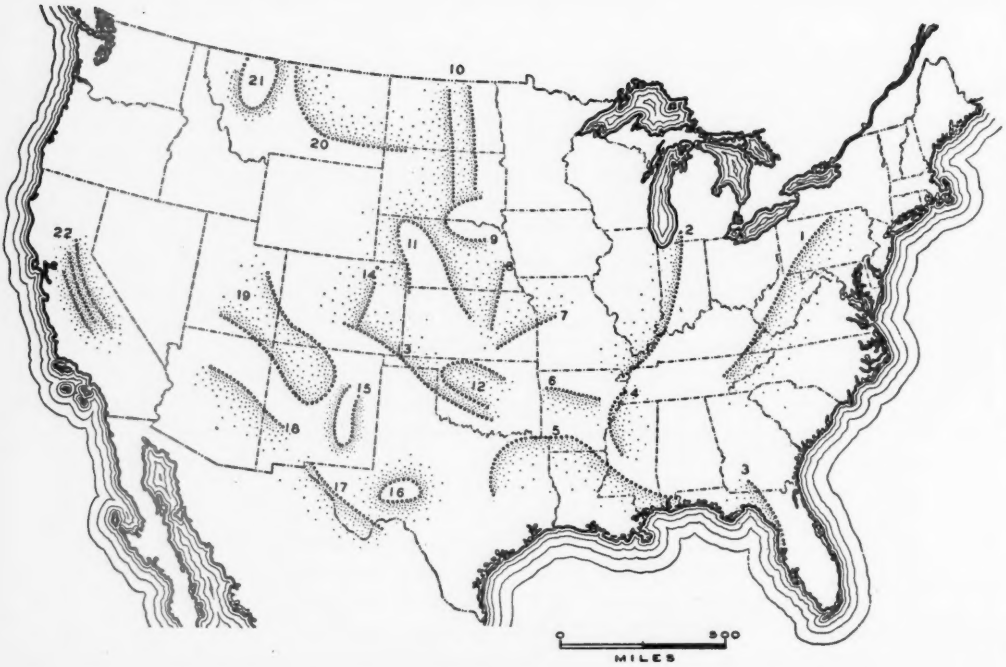

FIG. 17.—Outline map of United States showing more than 10,000 miles of well known essentially unexplored updip wedge belts of porosity. Confidential data in files of oil industry will probably double number and mileage of these belts and an additional like amount will undoubtedly be added during development of those now known. Prospective provinces shown are:

1. Updip westward wedging-out of early Paleozoic rocks which crop out in mountains on east.
2. Eastward wedging-out of St. Peter sand of middle Ordovician age.
3. Eastward wedging-out of thick sands of Eutaw and Tuscaloosa formations of Cretaceous age. See also Figure 16.
4. Overlapped, updip wedge of Eutaw and Tuscaloosa sands of Cretaceous age. See also Figure 16.
5. Wedge of rocks of Lower Cretaceous and Jurassic age which are producing in southern Arkansas. See also Figure 21.
6. Northward thinning-out of many Paleozoic formations.
7. Overlapped edge of upper and middle Ordovician formations on northwest flank of Ozark uplift.
8. Overlapped edges of entire pre-Pennsylvanian section along west flank of Nemaha granite ridge of Kansas and Nebraska.
9. Wedging-out of entire pre-Cretaceous section around Sioux uplift region of southeastern South Dakota.
10. Porous wedge belts of Jurassic to Ordovician age extending across Dakotas.
11. Wedging-out of all pre-Permian formations in western Nebraska as probable extension of Central Kansas uplift.
12. Wedging-out northwest and south of thick Pennsylvanian section of Anadarko basin of western Oklahoma.
13. Southward wedging-out of thick early Paleozoic rocks along north flank of Arbuckle-Amarillo uplift.
14. Eastward wedging-out of thick Pennsylvanian and Permian sands and arkoses along west flank of Sierra Grande arch of eastern Colorado.
15. Wedging-out of Pennsylvanian formations around Pedernal Hills uplift of eastern New Mexico.
16. Wedging-out of pre-Permian rocks around Fort Stockton "high" of West Texas.
17. Northeastward wedging-out of porous rocks of Lower Cretaceous age along Rio Grande in trans-Pecos area of West Texas.
18. Wedging-out of pre-Permian rocks along south side of Zuni-Fort Defiance-Grand Canyon area of New Mexico and Arizona.
19. Thick series of Pennsylvanian and older rocks which thin out north against Uncompahgre uplift of Colorado and south along Zuni-Fort Defiance-Grand Canyon arch of New Mexico and Arizona, and east around east side of San Juan basin in New Mexico.
20. South and west wedging-out of Big Snowy (Chester) series of upper Mississippian age.
21. Several sands in Cretaceous and Jurassic systems which thin out around Sweetgrass arch of northwestern Montana.
22. Numerous wedges of porosity in Eocene and Cretaceous rocks of central and northern San Joaquin Valley of California.

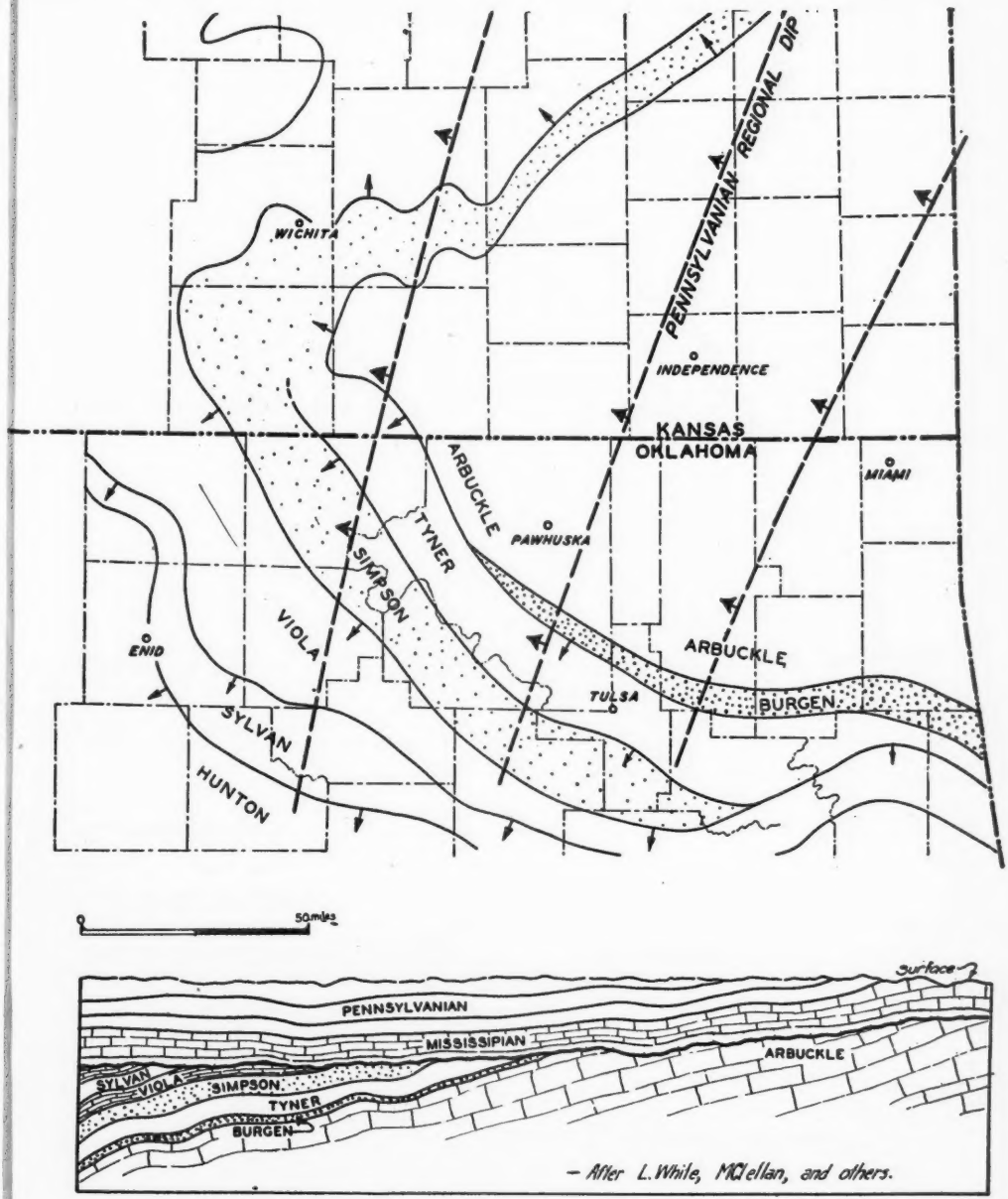

FIG. 18.—Southeastern Kansas and northeastern Oklahoma, showing two layers of geology. Upper layer, Pennsylvanian and Mississippian rocks, has regular north-northeast strike and west dip. Lower layer, Devonian and earlier rocks, is broad arch, pitching west, and forming west end of Ozark uplift. The two layers are separated by unconformity; general geology and petroleum geology are quite distinct in each layer.

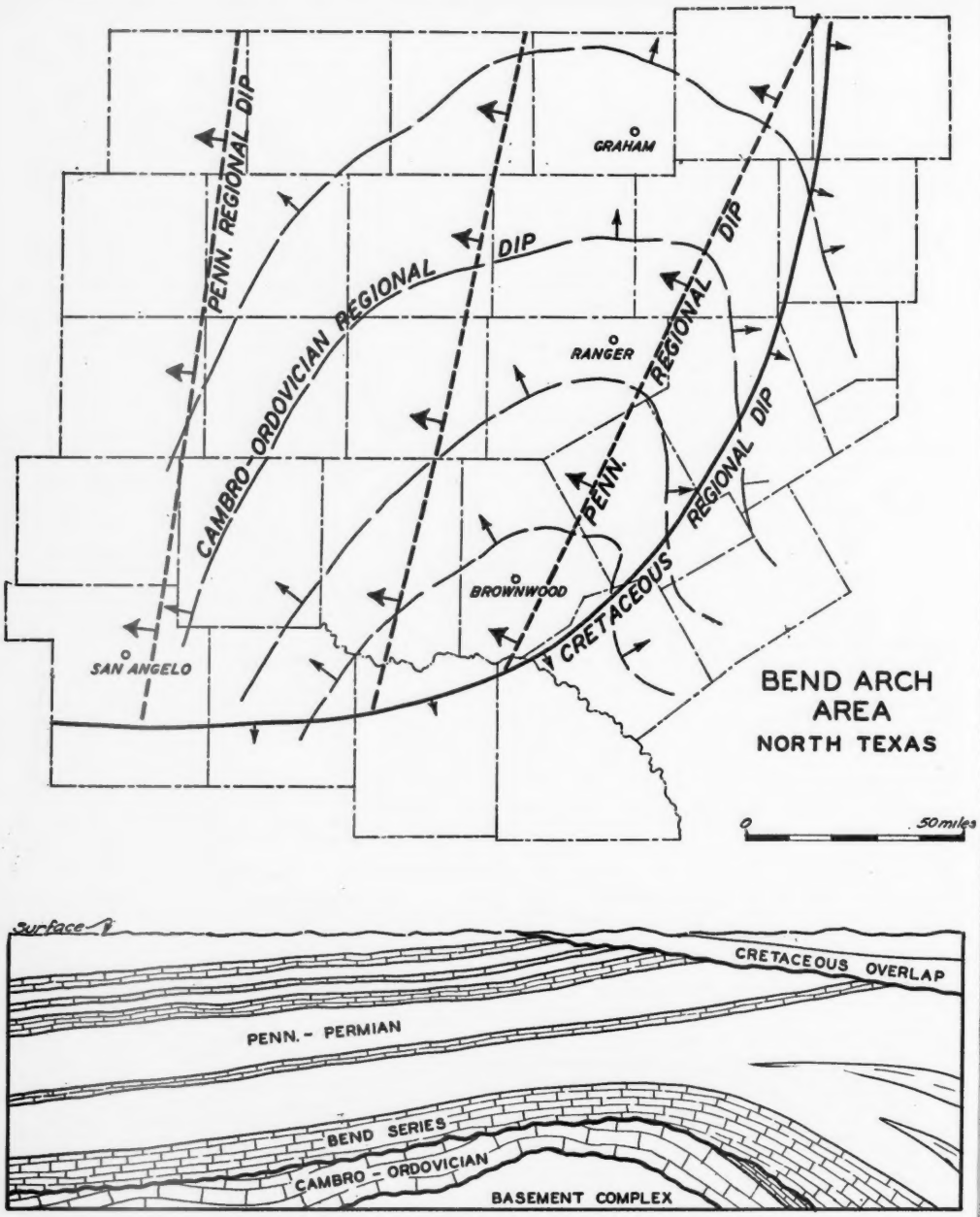

FIG. 19.—Bend arch region of north-central Texas in which three layers of geology exist. Upper layer, Cretaceous rocks, is broad southeastward-pitching arch. Below Cretaceous layer, Pennsylvanian layer strikes north and northeast and dips uniformly west. Below is Bend arch of lower Pennsylvanian, Mississippian, and Ordovician rocks. Each layer has its own petroleum geology, is separated from others by unconformities, and is quite independent of others.

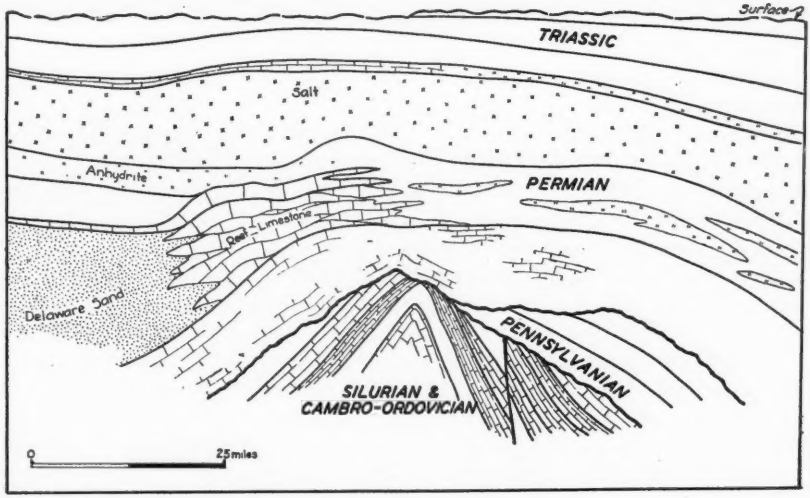

FIG. 20.—West Texas and southeastern New Mexico are underlain by several layers of geology. Upper layer of Triassic and Cretaceous rocks has uniform, low, southeastward dip. Permian, with its highly productive reef limestones grading into thick sandstones on one side and into anhydrites and shales on other, occurs next below. Underlying Permian is variable section of Pennsylvanian rocks ranging from thick dark shales to almost solid limestones. Next below is complicated layer of early Paleozoic (Devonian, Silurian, Ordovician, and Cambrian). Petroleum geology of each layer differs from each other layer; each layer is separated by unconformities; and each is quite independent of others.

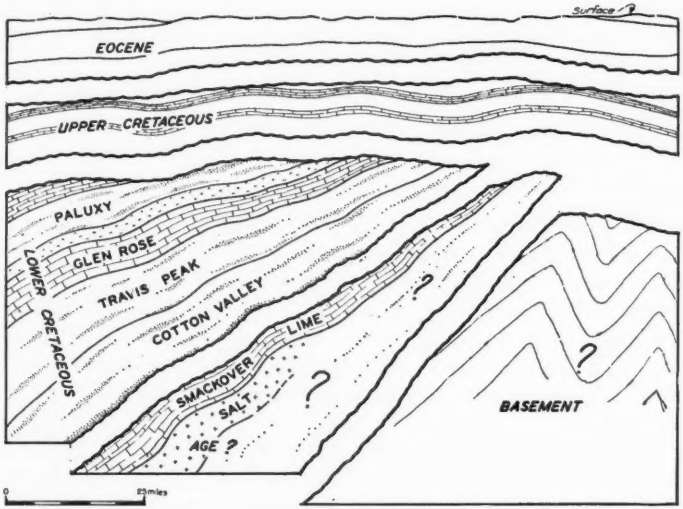

FIG. 21.—Northern Louisiana and southern Arkansas: another area in which numerous layers of geology are found superimposed, one on another. Layers are separated by unconformities; each has peculiarities of oil and gas geology; therefore each must be prospected differently from others, and each is independent of others. There are no clues in upper layers about what may be expected in next lower layer and each layer must be considered a unit.

discovered with additional drilling and at this time we can only guess at their extent and nature.

Typical of the better known areas where several layers of geology have been discovered are the four areas shown in Figures 18 to 21, inclusive. Each layer is separated from the other by an unconformity; each layer of geology is completely independent of other layers above and below; there is no clue in the upper layer of either the existence or the character of the next layer below; and each layer has its own oil and gas geology, completely independent from each of the other layers.

It is in this last characteristic that we particularly find application to the future discoveries of petroleum, for it means that no sedimentary area can be considered as explored until many test wells have been drilled through all of the layers of geology down to the basement rocks. As a matter of fact, every sedimentary region in the United States has unknown and unexplored geology waiting to be drilled. It is probable that there is a volume of undiscovered and therefore unknown and unexplored geology equal to that which is already explored, and it is inconceivable that these unexplored layers will not some day be translated into equally large volumes of oil and gas. The infinite complexity and at the same time the infinite opportunity in the petroleum geology of any locality becomes apparent when we remember that each layer has its own wedge belts of porosity, its own facies and lithologic changes, its own structural history, and its own oil and gas geology.

This concept as a part of one's thinking immediately gives hope and promise to countless square miles of territory which are at present condemned because of their monotonously uniform and uninteresting structure and stratigraphy when considered from the viewpoint of orthodox petroleum geology. As in a layer cake, where the sweetest layer may be deep in the cake, so with these layers of geology, the richest layer at any locality may be the second, or third, or fifth layer from the top, with no indication of its presence until the drill has crossed the overlying unconformity.

Discovery

A number of published surveys as well as numerous governmental hearings have shown the steadily declining rate of new oil discovery during recent years and 1942 appears to have one of the poorest records of all. This decline has been, according to Lahee,[5] in spite of an increase in the wildcat footage drilled and in spite of an increase in the total number of wildcat wells drilled. The new fields average smaller in size, and even if they are greater in number, the total amount of new oil discovered is annually becoming less and less. Obviously something is seriously wrong.

An attempt has been made to show that from two lines of geological thinking we have reason to believe there are still vast volumes of rocks in which geological conditions are known to exist which may reasonably be expected eventually to be-

[5] Frederic H. Lahee, "Wildcat Drilling in 1941 with Comments on Drilling Rate," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 6 (June, 1942), pp. 969–82.

come translated into equally large petroleum reserves. The question of the failing rate of discovery is then not yet to be answered by saying it is due to a lack of oil to be discovered.

On the other hand, the oil industry has spent vast quantities of money in an effort to make discoveries; it has established large and expensive exploration departments; and it has apparently spared no expense or effort in utilizing to the fullest extent everything that it thought might contribute to the finding effort. Great as this finding effort has been, it is not enough to do the job. Some think that an increase in the price of oil, a subsidy to the wildcatter, or some other form of increased advantage to those who are charged with discovery will result in the necessary increase in reserves. While it seems obvious that a prerequisite to any successful discovery program on a national scale is a price which will provide enough incentive to take the necessary risks, our particular concern, as petroleum geologists, is to increase discovery and decrease risk under whatever economy prevails.

It is often said that what the oil industry really needs is a new exploration tool, just as the fisherman needs some new tackle. But, like the fisherman analogy, when it is remembered that the new fishing tackle is generally designed to catch the eye of the fisherman and not necessarily the eye of the fish, it gives cause to wonder whether or not some of the new gadgets or devices continually coming into the discovery picture may be more of the nature to catch the eye of the contour-minded executive rather than the elusive oil field which it is hoped to find. Some of the most successful fishermen are those who use only the old-fashioned hook and line with a little bait, and maybe we can learn from them.

Whether the economic framework within which we must operate is good or bad, we have an unused tool as old as geology itself. It is simply—more geology. Not only should such a procedure prove effective, but it is relatively inexpensive as compared with current exploration costs, and in addition, it has the distinct advantage of being something with which we are now familiar. We can start off with it now without waiting for some unknown device to be discovered.

Before exploring the matter further, it might be well to point out that more geology means either more geologists, better pay for geology as such with a consequent better geology, or both. The young geologist, when he starts out, equipped with his full quota of ambition, energy, enthusiasm, and a desire to do things, looks about him and observes that the big-pay jobs are not for geology as such but for office, administrative, and production jobs in which geology merely furnishes the backgound. The well sitter or pipe setter is held in higher esteem than the oil finder. Is it any wonder that he gradually turns his attention and energy to the business of the oil industry and lets geology lag? He finds there is a salary level, different in different companies, yet nevertheless present, above which he can not rise as a geologist dealing in rocks, samples, and field observations, but which is readily penetrated if he can do administrative or office geology dealing in maps, appraisals, reports, surveys, and data secured by others. The fault is not with the

individual but with the system which gives so much more tangible recognition to the superficial and leaves the more fundamental factors to chance.

The correct identification of an unconformity, for example, and the correct interpretation of its meaning from well cuttings thousands of feet down in the ground, is not an administrative job; it can not be done by just anyone; and its identification may well be of greater direct importance to oil discovery than all of the other geological, geophysical, and administrative factors together. Yet almost any office job in the department is more desirable, pays better, and is more directly in line for further advancement.

When this Association began, more than 25 years ago, the objective of the few petroleum geologists then in existence was to find oil fields. Their full time was devoted to mapping and interpreting geological conditions with discovery as the objective. As time went on, and with the advent of geophysical methods, the rôle of discovery has gradually shifted to a large measure from the geologist as such, to the geophysicist, and the geologist is becoming more and more interested in the development of oil and gas which has already been discovered rather than in the discovery of new fields and new provinces. As a matter of fact, the modern oil-company geological organization has become a general service department. It serves the production department continually with geological advice on drilling wells, sitting on wells, advice on setting casing, advice on coring prospective sands, advice on well abandonments, and repeated advice as to whether the well is running high or low. It serves the land department with advice on rental payments, lease renewals, bonus payments, farm-outs, lease abandonments, and drilling deals. It serves the executive department with innumerable conferences and a continuous stream of reports, of statistical information, appraisals, competitive production records, and answers to the thousand and one questions that are always being asked. It serves the legal department as witnesses and developing evidence in lawsuits, and it serves the pipe-line department in advising on the prospects for discovery in the wildcat wells that are drilling near the company pipe lines. The geologist has in effect buried himself in routine service work.

All of this work is important to an oil company, and, in order to do it properly and efficiently, an increasing amount of administrative work becomes necessary. Governmental forms have to be filled out, voluminous records have to be kept and have to be instantly available, costs must be kept down, and all sorts of miscellaneous maps must be kept continually up-to-date. The daily conferences, reports, and administrative details, whether in the district offices or in the main office, require an ever increasing part of the total effort so that the thinking necessary to oil discovery gets secondary consideration or is turned over to the geophysicists. By his training, his ability to think in terms of earth variables, and his understanding of the problems involved, the geologist is particularly well fitted to do all of these tasks which have been assigned to him, and all of them are necessary and desirable, not only for the company but for the geologist as well. They give a stability to his employment and a constantly visible reason for his existence which

is most comforting. But, they are not directly concerned with the thing which he can do best and which is of greatest importance to the petroleum industry, and that is the discovery of new oil fields.

In an attempt to analyze further the modern discovery process, a survey was made of the number of seismograph units as compared with the number of geologists in seventeen representative oil-company exploration departments. The results are shown in Figure 22. It is seen that the number of geologists per seismograph ranges from 3 to 9. If an average figure of $10,000 per month be used as the

RATIOS —. GEOLOGISTS TO SEISMOGRAPHS

Company	Seismographs	Geologists	Geologists per Seismograph
A	3	9	3.
B	2	8	4.
C	10	40	4.
D	16	48	4.
E	23	97	4.+
F	9	41	4.5
G	15	85	5.7
H	8	46	5.7
I	11	64	5.8
J	4	24	6.
K	16	98	6.+
L	4	30	7.5
M	5	38	7.6
N	8	66	8.2
O	6	50	8.3
P	6	50	8.3
Q	4	36	9.
TOTALS	150	830	
AVERAGES	9-	49-	5.5

FIG. 22.—Ratios of geologists to seismographs in exploration departments of 17 typical oil companies operating in United States outside of California.

cost of a seismograph and $500 per month be used as the average cost of a geologist, which includes office help, draftsmen, and filing clerks attached to the geological department, it is seen that the money spent on geologists ranges from 15 to 45 per cent of the amount spent on seismic surveying. The average is 30 per cent.

As has been pointed out, the modern geological department spends only a relatively small part of its time in searching for new oil fields and by far the major effort—probably fully 90 per cent—on routine connected with production and development problems in fields which have already been discovered, and on routine clerical and administrative work. The amount of money spent directly by the geological department in search for new oil and gas fields—in what might be called "discovery thinking"—is thus only an average of one-tenth of the 30 per cent, or 3 per cent of the amount spent by the geophysical department, when these two departments are considered separately.

Stated still differently, all of the money spent on seismic surveying, plus most of the small part of geology devoted to discovery, goes into a search for structures, in which it is *hoped* oil will be found. When one remembers that at least a third and probably half of the past production and present reserves are located primarily as a result of some stratigraphic variation or anomaly of sedimentation, and in addition, as has been shown, that even most regions where the individual oil pools are structural, the province as a whole is fundamentally related to major stratigraphic variations called wedge belts of porosity, it is seen that the big majority of all our past discoveries have in them a stratigraphic factor, either directly or indirectly responsible for the accumulation of oil. Since most of the 3 per cent of the strictly geological time and thought spent on discovery is concerned chiefly with structural studies, we might truthfully say that less than one per cent of our total discovery effort—both geological and geophysical—is devoted to the kind of geology which is known to be responsible, either wholly or in part, for most of our oil. It does not make good sense.

Nothing herein should be interpreted as meaning there should be less seismic surveying, but rather that there should be a greater proportion of geology put into the exploration effort. Not only is it proposed that a greater proportion of geology be employed but that this increase be devoted primarily to discovery rather than to development. There are many geological discovery tools rusting away in our kit for want of use. The need is for "creative" geology as compared with what may be called "routine" geology.

An opportunity must be provided for those men with the capacity and with the ability for doing creative geology to actually do geology, and in addition, to be able to spend a part of their time with their feet on a desk looking out of the window where they can generate ideas and where they can reconstruct in their mind the conditions and the environments of past geologic ages. What we need is more of the sort of geology that Philip King did in West Texas and New Mexico, or the kind that Marshall Kay is doing in the Appalachians, or that Ross Heaton has done in the Rocky Mountains, or the kind that was so ably done by Ralph Reed in California. There are enough discovery ideas and prospective provinces in reports such as they have published to justify any operator looking for new ideas to keep men continuously on this sort of work as a practical and economical oil-finding attack.

We have been inclined to lean too heavily on mechanical devices to carry on the discovery process for us and not enough on coördinated personal observation, individual interpretation and understanding. These mechanical crutches, if used too long or too intensively, gradually dull our ability to carry our discovery thinking through to a successful answer, and, as we become increasingly dependent on outside help, we become decreasingly able to do without it. The unused talent finally is lost.

There are several kinds of geology, the doing of which should result in more discovery, and a few of them are discussed in the part which follows.

WEDGE BELTS OF POROSITY AND LAYERS OF GEOLOGY

If you agree that wedge belts of porosity are commonly a fundamental prerequisite of an oil province and that successive layers of unknown geology underlie much of the sedimentary region of the United States, then you must reach the conclusion that the only known way of reducing these conditions to practical application is through a strictly geological approach. Such an approach means the preparation and study of facies maps, lithologic maps, isopach maps, paleogeographic maps, paleogeologic maps, quantitative and qualitative sedimentation studies, and detailed stratigraphic analyses of every porous sedimentary rock unit in the United States and eventually in the world. It means a resolving of the great mass of geophysical data into stratigraphy and sedimentology as well as into structural geology. The basis for this work is first, a restudy of all surface rocks most of which will have to be re-examined from a stratigraphic and sedimentational viewpoint as well as structurally; and second, a restudy of the detailed subsurface data now in the files and laboratories of the oil industry in the form of well cuttings, cores, electric logs, porosity and permeability measurements, water, oil and gas content, geophysical and geochemical data, and anything which will throw light on the location of a wedge edge of porosity or the crossing of an unconformity into new and unexplored geological conditions.

When you accept into your geological thinking the philosophy of wedge belts of porosity and layers of geology, you must at the same time agree that there remains many times as much fundamental commercial geology to be done as has been done in all of our past geological experience. Most of the information in the unexplored regions is and always will be fragmentary and inconclusive, and it is for this reason more than any other, that experienced, broadly trained, and speculative-minded men will have to be developed. Moreover, this kind of geology is not the type that can ordinarily be done as a casual task between conferences, but it is the kind that will require hours, months, and years of the most careful study, thoughtful analysis, and imagination without end.

LIMESTONE-REEF FIELDS

Petroleum geologists in West Texas and New Mexico, working with the limestones and dolomites of Permian age, have led the way to a better understanding of the rôle that limestone reefs play in the accumulation of oil and gas. While there is a voluminous geologic literature concerned with the problem as it is developed in the Permian basin, there is little or no work being done on the larger problem of reef production generally. Reef production is not confined by any means to the Permian basin. The southern fields, or "Golden Lane" of Mexico, for example, produce their oil from reef limestones in the middle Cretaceous. Undoubtedly much of the early Devonian production in southern Ontario is related to reef-like deposits, and many wells of thousands of barrels daily pro-

duction were found at exceptionally shallow depths. Likewise, the limestones producing in Michigan probably have in many of them reef elements of which a better understanding would provide more discovery.

A few years ago, Laudon and Bowsher described the numerous reef deposits which crop out in the Mississippian limestones of southeastern New Mexico[6] and now we learn of a number of rich oil pools being found in similar but buried Mississippian limestone reefs in the North Texas region. Even more exceptional are the several pools producing from thick limestone reef material in the otherwise uniformly bedded shales and thin sands and limestones of the Pennsylvanian of North Texas.[7]

There are enough oil pools which are now known to produce from limestone reefs or from reef-like deposits to justify the conclusion that there are a great many more yet to be discovered. Every company concerned with the discovery might well have an expert on "reef" production—a person of broad geological experience, skilled in the interpretation of geological conditions from well cuttings, able to visualize subsurface conditions and geological environments, and one who would devote his entire working time over a period of years to this problem. The problem of reef production is fundamentally geological and the cost of such work in terms of the discovery possibilities is insignificant.

LENSING AND SHOESTRING SANDS

The amount of production from shoestring and lensing sands in the United States is probably much greater than is generally supposed. Individual pools are both large and small, there are many of them, and in the aggregate they account for a substantial part of the national supply. There are dozens of such pools in Pennsylvania, in West Virginia, in Ohio, Illinois, Indiana and Kentucky, in Kansas, in Oklahoma, and in Texas, and with very few exceptions they were discovered without benefit of geology, geophysics, or much, if any, scientific reasoning.

There was a time during the development of the shoestring and lensing sands of southeastern Kansas and northeastern Oklahoma when they attracted considerable scientific interest and articles descriptive of them were published by Rich, Cadman, Charles, and others. When the shoestring sands of Greenwood County, Kansas, were being first developed, Sidney Powers was much concerned over their origin and how they might be more scientifically prospected. He was particularly interested in getting different views and explanations of some of the possible origins and once said, "I hope before they are all developed that someone who has seen a sand bar along the ocean shore will become interested in studying them. As a matter of fact," he continued, "those who are doing all of the present

[6] L. R. Laudon and A. L. Bowsher, "Mississippian Formations of Sacramento Mountains, New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 12 (December, 1941), pp. 2107–60.

[7] J. K. Murphy, Paul E. M. Purcell, and H. E. Barton, "Seymour Pool, Baylor County, Texas," *Stratigraphic Type Oil Fields*, Amer. Assoc. Petrol. Geol. (1941), pp. 760–75.

philosophizing are 100 per cent landlubbers and I have a hunch that these are not stream channels but are buried ocean sand bars. I would be most happy to have someone who has even seen the ocean take a look at them."

Bass[8] went to the ocean and came out with his classic shoestring sand studies which answered for a long time many of the perplexing questions about these deposits. Since then, however, interest has lagged and apparently the oil industry is content to leave their future discovery to the random wildcatter as in the past.

Yet, here is a field of study which most certainly will yield results if attacked scientifically. Such attack would be purely geological in nature and probably largely in the field of detailed sedimentology. It would depend in a large measure on a thorough understanding of all the phenomena of sand deposition along varying sea coasts, on the ecology of such regions, and on the ability to identify sand forms accurately with few data. Is it not probable that detailed sedimentation studies will enable one skilled in lensing sands to tell whether the test well is on the lagoonal side of the sand bar or on the offshore side? And thereby accurately advise which direction to move in order to encounter more sand? Or whether the well is near the end or the sides of the sand deposit? Or that the sand encountered is a stray sand or a blanket sand? Sedimentationists are thinking in these terms and one has only to read the writings of Krumbein, Pettijohn, Krynine, Russell, and others, to see that they are thinking in terms far in advance of what we as commercial geologists are content to call satisfactory.

In terms of probable results, the cost of keeping experienced geologists on this type of exploration problem over a period of years in negligible. As in other fields of geology, however, it is a kind of work that calls for broad experience, imagination, keen interest in the geological problems involved, and the confidence of the management which will permit much drilling on reasons that might now be called unorthodox. Any oil company looking to the future might well put one or more geologists permanently on such work, men who will eventually become expert in the identification, prediction, and understanding of this much neglected type of production.

DETAILED SURFACE STRUCTURAL MAPPING

We hear it said that the day of surface mapping is over. Certainly it has declined in importance in the normal exploration programs to the point where it is often difficult to find geologists capable of doing even an ordinary detail job when such emergencies develop. It is probably true that the hey-day of reconnaissance surface mapping is past in the United States but it can be seriously questioned whether detailed plane-table mapping is not still an extremely effective discovery tool. There has been done actually only a relatively small amount of really careful, detailed surface plane-table mapping, particularly with the assistance of aerial photographs. Over and over again we hear of geophysical or subsurface

[8] N. W. Bass, "Origin of the Shoestring Sands of Greenwood and Butler Counties, Kansas," *Kansas Geol. Survey Bull. 23* (September, 1936).

prospects which it is later remembered or determined underlie surface anomalies, and we likewise hear of geophysical and subsurface failures which underlie readily workable yet perfectly normal surface structures. The value of detailed surface geological mapping is too often recognized after it is too late rather than as a primary discovery technique.

Two examples of recent discoveries resulting from surface mapping show that such methods are by no means ready to be put on the shelf. The first is the discovery of the East Watchorn pool in T. 23 N., R. 3 E., Pawnee County, Oklahoma, by the Alma Oil Company. Everett Carpenter, known to many of you as having practiced petroleum geology in the Mid-Continent region for the past 30 years, was in the employ of the Alma Company looking after some drilling in the old Watchorn pool. While driving back and forth to work he observed some abnormal surface dips and spent two or three days in working out a rather detailed reconnaissance map of the area of the disturbance.

On the basis of this work the Alma Oil Company decided to shoot the area and results of variable quality were obtained, probably due to the considerable alluvium in the area. Enough was indicated, which, when added to the surface mapping, caused the company to take a block of leases at a dollar per acre and drill a test well. The result was the discovery, in the "Wilcox" sand, of the East Watchorn pool, which it is interesting to note follows the surface mapping more closely than it does the seismic interpretation.

Two things stand out in this case history. First, if it had not been for the fact that Everett Carpenter, with his wealth of experience, was actually out in the field looking for surface anomalies, there would probably still be no pool known at this locality; and second, it is absurd to say that even in such an old and established area as northern Oklahoma the surface geology has been adequately mapped when a structure such as this can be discovered by reconnaissance methods.

The second example of discovery resulting from surface mapping is that of the Hawkins field in Wood County, northeastern Texas, as told to me by Morgan Davis. This area was mapped by E. A. Wendlandt, of the Humble Oil and Refining Company, in the summer of 1930. At that time not much significance was attached to the structure since it appeared relatively insignificant in comparison with other structures in the basin. However, in 1933 and 1934, the Long Lake and Cuyuga fields were opened under small surface structures and the Humble Company leased a small block of leases on the fold which Wendlandt had mapped. Results from seismograph surveys were poor and thought was given to dropping the block of leases or farming it out.

However, in 1937, at the insistence of Wendlandt that the area had possibilities, it was core-drilled under the direction of T. J. Burnett with the result that the company acquired a much larger area of leases.

Although the Humble Company did not actually make the discovery, their intention was to drill a test well and they were curing titles when Manziel com-

pleted his discovery well in December, 1940, at a location which later marked the edge of the pool. Their block of 7,000 acres of leases now has 361 wells and an oil reserve on the order of 400,000,000 barrels.

Here, too, the lesson to be learned is that surface detail work pays big dividends when done by one with experience and skill in this kind of geology. When done right it deserves top consideration in the search for oil fields.

Another lesson is that here is an enormous reserve under an apparently insignificant structural anomaly. It must have been classified far down on the Humble's list of prospects for many years. Yet, when unconformities and variable geological history are added to what appeared to be fourth- or fifth-rate prospects, they have a way of changing into something entirely unforeseen and unexpected.

These are only two examples of many that might be presented to show that there is still a place for surface mapping; that it leads to oil and gas discovery; and that it is not a kind of work to leave entirely to the young geologist; but that it can be most effectively done by men of experience—which also means such men must go where the outcrops are located. In surface geological mapping more attention than heretofore should be given to the sedimentary variations, facies changes, and stratigraphic studies which will bring it into more practical relation to subsurface studies, wedge belts of porosity, and problems related to overlaps, unconformities, and local and regional geologic history. Moreover, when it is remembered that eight or ten experienced plane-table parties can be kept continuously in the field for the equivalent cost of one seismograph crew, the cost in relation to oil discovery is insignificant.

COÖRDINATION OF DATA

In the language of the automobile manufacturer, every oil field may be called a "custom-built job." Superficially they may look alike, but if we lift the hood we find the insides vary from field to field. They differ in geologic history, in structural development, in sedimentary and stratigraphic relationships, in position with respect to the basins, in reservoir-rock conditions, and in the physics of the contained liquids and gases. The possible combinations of conditions are almost infinite in their variety. This leads to the conclusion that each oil field is different from every other field and that the next field to be discovered will have a combination of geological factors different from anything that has been seen before,—it will in fact be a new geological experience.

There is much in the science of geology besides structural geology which can be applied to the discovery of new oil and gas fields. Yet we persist in applying mass-production methods—in our case we might call it mass structure surveying as practically the sole discovery tool. True, geologic structure is the most obvious, the most readily determined, and therefore the most quickly exhausted of any of the factors which it is believed have a bearing on the occurrence of oil and gas, but it is by no means the whole answer. And even in our structural work, we find ourselves too often adhering to one of the several kinds of structural sur-

veying— surface, subsurface, or geophysical—to the exclusion of the others. The discovery process is complex and we dare not leave it to any single method or technique. With the several dozen kinds of devices for obtaining detailed and accurate geologic data of all kinds, our problem of blending, coördinating, and interpreting all of this information, and putting it to work in discovery becomes more and more important.

The story of the discovery of the Pauls Valley field in Garvin County, Oklahoma, well illustrates the possibilities of coördinating variable data by one with broad geological experience. As far back as 1928, Ira Cram, then district geologist for the Pure Oil Company, recognized the fundamentally favorable regionally high structure of the area, and started working on it. In an effort to localize structural closure on this broad arch, surface detail mapping was done which resulted in some ideas, but generally the beds exposed were such that detail mapping was impossible over much of the area. Magnetic work failed to show anything of interest and, in 1933, seismic operations were commenced. The subsurface geology was complex and the difficulties of intepretation were great, but during seismic reconnaissance, enough encouragment was obtained to justify the leasing of several anomalies, one of which later included the Pauls Valley pool.

Between 1934 and 1937, thirteen Ordovician dry holes were completed in the Pauls Valley district, none of which offered any definite promise of future discovery. Cram, however, re-examined all of the seismic data in the light of the detailed sample information revealed by these dry holes, coördinated the information, and as a result, reworked the geology of the entire area. From this restudy, the geologic history was worked out with fair accuracy, additional detailed seismic work performed, and relationships were established which had been indefinite or merely suggested.

Between 1937 and 1941, four more dry holes were drilled by other companies, all of them in the vicinity of what is now the Pauls Valley field, but none of them gave any indication of the presence of commercial oil. These later holes, however, did confirm the geological interpretation which had been developed as the result of the detailed geological and seismic work, and in 1942, the Pure Oil Company's Teter No. 1 was drilled in Sec. 31, T. 4 N., R. 1 E., Garvin County, Oklahoma, as the discovery well of the Pauls Valley field. Production was obtained in the Bromide sand of Ordovician age and there are now 14 flowing wells in the pool and the limits are not yet defined.

Many other companies held leases in the vicinity and many geologists at one time or another saw the possibilities of the area. However, the continuously discouraging results of 17 dry holes drilled during the 8 years between 1934 and 1942 dulled their enthusiasm, and the general opinion of the possibilities of the area at the time of the Pure discovery was far from favorable.

The lesson for all of us in this discovery is that if it had not been for the persistence of Cram, his technical experience and interpretive ability to coördinate

detailed well-cutting data, surface structural maps, and geologic history with geophysical data, and the faith the Pure Oil Company placed in his judgment in drilling when nearly everyone else had given up hope, the Pauls Valley field would still be undiscovered and probably would remain unknown for many years to come. How many more similar areas are now lying in the files, more or less condemned, yet waiting to be reworked in the light of modern concepts, with modern tools, by men of experience and with the ability to coördinate geology, geophysics, and all the host of technical data now available, and with the imagination necessary to visualize geological history in terms of oil and gas accumulation? Nearly every company has prospects by the dozen such as this, just waiting for a fresh viewpoint, a restudy, or a more experienced attack to transform them from something of merely historical interest into something of potential future worth.

GEOLOGICAL RESEARCH

The time is rapidly approaching when some extensive fundamental research is called for in petroleum geology. Most of the research laboratories of the oil companies are devoted chiefly to studies of refined products, new uses for petroleum, development of geophysical instruments, and development of engineering and production principles and techniques. In these modern research laboratories, as well as in the exploration departments, we find the main efforts are directed chiefly toward the improved utilization of petroleum which is already discovered or produced rather than toward the more fundamental problem of discovering new supplies to replace those that are now being consumed.

If there is any doubt as to the ability of the industry to maintain a supply of petroleum through the years ahead—and we all realize there is such a doubt—then through some means or other, research on many of the fundamental questions concerning the occurrence of petroleum can not start too soon. Most of our oil provinces have been discovered contrary to the orthodox geological opinion prevailing at the time, which is rather good evidence that our fundamental thinking is not sound. Other industries, which use petroleum products, are developing new uses through research, but our thinking has been standing still on the problem of discovering the supplies these increased demands call for.

An industry that spends a quarter of a billion dollars or more each year on exploration can well afford to set aside a small percentage of this money in an attempt to make the effort more effective, if not to save the entire situation. This is in fact a public responsibility. It can be done as a broad industry-wide approach as is being done on a small scale by some members of the American Petroleum Institute in the study of the origin of petroleum, or it can be justified as a legitimate private-company expense if only for the simple reason that it is a practical and economical insurance against the day of insufficient supply.

Some of the subjects of research that can be studied profitably are suggested in the following section.

SOURCE ROCKS

"What is it and where does it come from?" has been a question in the minds of many since the first oil, pitch, or asphalt was discovered in the beginnings of human history. At no time, however, has there been any demonstrable proof of the mode of its origin and, although there have always been many theories and explanations, even to-day we have nothing on which we can depend as satisfactory. As a matter of fact, the most recent thought on the question of the origin of petroleum indicates that it may well be a much more complex and involved process involving chemistry, bacteriology, physics, and geology, than anything we have even thought of heretofore. The more we know of the subject, the more difficult appears to be the answer.

Yet, in spite of the evident lack of information, the oil industry has either spent or withheld millions of dollars and great quantities of time and materials, on what was the currently prevalent thought on the subject. As long as discovery was adequate, the question of origin was of purely academic interest, and it did not make much, if any, vital difference to anyone what the ideas were on the source material of petroleum—whether it was the urine of whales as some early investigators thought, or the product of subterranean volcanism as was thought by others, or the organic material deposited in marine sediments according to more modern ideas.

The chief geologist of one of the major companies told me last summer that while attending college, and after considering the subject of source rocks, he wrote a thesis with the title, "Why It Is Impossible to Find Oil in West Texas," and it received much favorable comment from the faculty. That was the prevalent thought of the time and it acted as a stone wall beyond which the orthodox geologist was unable to see. The presence or absence of source rocks in West Texas was the chief fundamental criterion on which exploration out there was either done or not done. In the early twenties it was a real stroke of luck for the Gulf Company to have on its staff men like Kip Harper and Ben Belt, who had escaped in some manner from the mental fence concerning the lack of source rocks in West Texas, within which the average geologist had retreated. Thus, while one company with a liberal viewpoint on this question acquired many millions of barrels of oil, the others, largely because of a different viewpoint on this one question, were prevented from participation.

Now, as a matter of fact, no one at that time knew whether or not there were source rocks in West Texas for the simple reason that even to-day no one knows what a source rock is. The chief reasoning on which the prospecting or lack of prospecting was based was prejudice—pre-judging—and insofar as a source rock is concerned, it is still prejudice. Yet the argument comes up continually that an area is unfavorable because it does not contain a "source rock." "I like to see some black shales, or at least some dark shales," "There ought to be some fossils in all that limestone to indicate a source rock," "where is your source rock," or a similar expression of doubt is a common excuse for not drilling in new territory.

Is it not ordinary common sense to spend some money on trying to find out something definite about source rocks? Or at least to recognize applications to which lack of such knowledge applies? How many future productive areas will be condemned because some geologist thinks there are no source rocks? With the exception of the relatively small appropriations available to the A.P.I. research committee, in the work of Trask and the present project on the origin of oil, there has been only intermittent and casual interest in the subject of the source material of our oil fields. Yet the industry is paying in a big way for its lack of such knowledge and will continue to pay in a big way until something is done about it.

FRESH OR LOW-CONCENTRATION WATER

A few years ago if one were to listen to the average geological conversation in the offices or on the streets of Tulsa—and probably in many other towns in the northern Mid-Continent area—he would probably hear a heated argument on the possibilities of oil and gas in the Forest City basin of northwestern Missouri. This area was very much in the limelight at that time and attention was directed toward it largely because of its similarity with the Michigan basin and the Illinois basin, both of which had been proved productive. There was something different, however, in the Forest City basin and that was that the older formations were known to contain either fresh or low-concentration waters. What did it mean? Some said that it meant there would be no commercial oil fields—and so far at least they have not been disproved. Other companies thought that such a condition was not particularly detrimental and they waived this objection and sent geologists and lease men into the area and later drilled test wells there. In the aggregate, large sums of money were either spent or withheld by various companies largely dependent on the philosophy or attitude of their geologists toward this question of the influence of fresh water on oil accumulation.

As in the case of source rocks, the interesting fact is that no one has yet shown any demonstrable reason or observation that fresh or low-concentration waters have any significance either for or against the accumulation of oil and gas. In other words, we know nothing about it, yet this lack of knowledge in the form of prejudices—pre-judging—translates into untold amounts of money, time, and effort either withheld or spent. A small percentage of the money involved, if applied to research on the question of the function of such waters in oil accumulation, may or may not give the answer, but the problem certainly would be put into a form that the industry could evaluate more correctly than at present and it would not be dependent on half-baked theories, most of which "jelled" while in college.

When oil fields such as some of those in northern Sumatra, in Venezuela, and in our Rocky Mountains, are found to occur associated with fresh or nearly fresh waters, how many others might there be in areas that are now condemned for this reason? There are too many oil fields throughout the world in which oil is being produced along with or in close association with fresh or low-concentration waters to continue our present loose thinking on this subject.

SEDIMENTATION

Sedimentation, with all of its related studies, promises to be of increasing importance and one of the key discovery tools of the future. Some of its possible applications have been pointed out and we may well see the day when it rivals structural geology as a way of finding oil.

Yet, we must admit, that in spite of the magnificent work that has been done in the past by the little band of sedimentationists scattered through some of the college geology departments of the country, we really have made only a start on a workable understanding of the subject as it can be applied to petroleum geology. Every oil field in the world involves sediments of some kind, and those sediments, whatever their character, are more intimately associated with the oil and gas than any other factor. In addition, they either precede, or are contemporaneous with, the formation of the oil.

In our approach to discovery, however, sedimentation as a practical scientific device to find new oil fields or extend old ones is almost ignored. Probably one reason for this lack of appreciation by the industry generally is that the sedimentationists have not yet discovered a way of presenting their ideas in the form of contour maps with some kind of a closed-contour symbol indicating the favorable areas for drilling. Let us not forget that in spite of this oversight which may some day be corrected, these men have ideas that may profoundly change our prospecting technique.

Gradually coming into the picture are the quantitative methods exemplified by the work of Krumbein, Pettijohn, and Russell; the application to basic problems of oil movement and reservoir conditions as developed by Waldschmidt; the single-handed attack on many of our fundamental problems in petroleum geology that is being made by Krynine; and over it all the balanced thinking of Twenhofel. All of this pioneer work is being done by men in colleges and is without cost to the oil industry. Almost the only really fundamental work being done by the oil industry on sediments is with clays, and then only because of their application to drilling muds.

An inkling of what is ahead of us in sedimentation was well stated by Payne in a recent issue of our *Bulletin*.[9]

> It is now coming to be realized that the future must bring a new form of stratigraphic research, middle-road research which will bridge the gap between the *old stratigraphy* and the *new stratigraphy* that is now unfolding. This middle-road policy will call for complete restudy of the stratigraphic record and for lithologic descriptions and environmental interpretations which recognize and evaluate in simple semi-quantitative manner the fundamental attributes, properties, and structures of sediments and the environmental factors and sedimentational processes which control its genesis.
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> . . . The new stratigraphy must include a breakdown of the stratigraphic record into lithologic and environmental types and their varieties and must place emphasis on *lithologic classification* as well as stratigraphic classification.

[9] Thomas G. Payne, "Stratigraphical Analysis and Environmental Reconstruction," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 11 (November, 1942), pp. 1698 and 1699.

A real understanding of sediments would probably do more than any other single factor to improve the geological interpretations which are put on geophysical data and in like manner it would improve the speculative geology which is necessary to all subsurface studies. Would it not be wise for the oil industry, either collectively or individually, to set aside even an infinitesimal fraction of its discovery costs to gain a better understanding of one of the very few factors common to all oil fields? Especially since our present knowledge has merely touched the fringes of a phase of geology, the applications of which even now give indication of being critical to much of our future discovery thinking?

PERSONNEL

A very practical and natural question in times such as these is where to find the men to do the geological work which has been described. There is probably no complete answer until the war is over. There are, however, several partial solutions, which taken together may help to tide over the situation. They are these.

First: "First things first." When the problem of first importance becomes the discovery of new oil fields and not the development of old ones, there will be many geologists now doing routine or "hack" geology in local areas who can be advanced to the more important creative job of discovery in new areas. They can be put into the field or they can be trained to interpret, in terms of discovery, some of the volume of data, the collection and filing of which is now their chief concern.

Second: Many is the consulting geologist with a background of broad experience and with the technical ability to take on problems such as have been described. The discovery showing which they as a group continue to make with the small amounts of information, equipment, and money they have available strongly suggests that with more data to work with they would have commensurately greater results. Probably one reason for their success is that they know they can not make a living if their objective is merely to collect and file information; as a consequence, they learn to think in terms of discovery and direct their supreme effort toward that end.

Third: With the falling-off in college enrollments in geology departments there are many instructors, assistants, and professors who will be available for commercial engagements. There are literally thousands of special geological reports of the type previously suggested, waiting to be made and which they can make equally as well as, or even more intelligently than, the strictly commercial geologist.

CONCLUSION

In conclusion, what has been said resolves into the simple statement that the oil industry is by-passing an important discovery tool. It has attempted to mechanize, routinize, and standardize what DeGolyer has so aptly termed the "art

of discovery"—an inherently individualized and infinitely variable process—and the job is not being done. The proposal is to return to geology as such, but on a much higher scientific level than heretofore. As a discovery tool, there is enough geology now rusting away in the sheds of our filing cabinets and in the background of our thinking to cultivate a really substantial and continuous crop of new oil fields. We have, in the form of more geological observation, more geological reasoning, and more geological understanding, discovery tools that will take hold as our present methods let go, and they are fully able to carry, not only the geologist but the oil industry itself, to new levels of achievement. Moreover, the United States is the great proving ground for exploration ideas and the problems we have here and the solutions we get become the guide to discovery throughout the world. If we are only encouraged and permitted to exercise our latent abilities we can do much toward lifting the clouds of doubt and uncertainty concerning our oil supplies which have settled round about us. This means that all of us must think discovery if we are to realize it.

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THE PETROLEUM GEOLOGIST IN THE WAR[1]

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INTRODUCTION

Not so many years ago geology was studied and used in a purely scientific manner, but later practical applications began to be made in the mining industry and the development of the natural resources. Then all of a sudden, a geologist, I. C. White, expounded the anticlinal theory of oil accumulation, although others may have suspected the condition at an earlier date. From that time on, the parade of progress for the geologist in the petroleum industry became a reality. The efforts of the geologist were received with considerable skepticism and ridicule, but this did not stop him. The operators in that day were using practical geology to some extent without knowing it and that word "Geology" when mentioned was beyond their comprehension and was taboo; at any rate, in spite of all this, the petroleum industry grudgingly and gradually accepted the geologist. As time went on he has become one of the most important members of its organizations in the exploration and development of oil fields. In more recent years, the geophysicist has entered the field, and, together with the petroleum geologist, has been the means of discovering many great oil fields. At the present time, both of them are working hand in hand to prospect and explore for new reserves and do their utmost, not only to replace depleted reserves, but also to discover and conserve new fields and new producing formations. In this gradual climb to a place of prominence in industries, the geologist has learned by experience to use all the skill at his command and be very resourceful in his work—with a record hardly equalled by any other professional group. There are approximately 4,500 geologists in the Western Hemisphere and at least 4,000 of them are, or have been, engaged directly or indirectly in the petroleum industry. To say that the American petroleum geologist is superior to others in the technique of discovery and development of petroleum reserves is not an exaggeration. He has been used all over the world and is being used in many parts of it now, in spite of World War conditions, to do the special kind of work for which he is so well trained and experienced.

WORLD WAR NO. II

The attack on Pearl Harbor, December 7, 1941, and the events which followed disrupted the normal life of petroleum geologists. Many of them were in foreign areas subject to attack. While many of them returned to the United States, others stayed and became a part of the military or civilian forces. From observation of, and contact with, so many petroleum and other geologists, I am of the opinion

[1] Address of the president, twenty-eighth annual meeting of the Association, Fort Worth, April 8, 1943.

[2] Southland Royalty Company.

that they are one of the most patriotic groups in our country and Allied Nations—whether it be in military or civilian capacities, in Government work, or in essential industry directly connected with the war effort. You would be very much interested to know, but not surprised to learn, of the interest that the petroleum and other geologists have taken in military affairs. Many of our younger groups, and even some of the older ones, being reserve officers, were soon called into service, while hundreds of others have volunteered for active participation. In anticipation of this situation, the national service committee of the A.A.P.G., in cooperation with the war effort committee of the Geological Society of America and others, made some progress in interesting the military authorities in the skills, training, and experience of the geologist. Our principal objective in the whole matter was to interest the Armed Forces in the effective and efficient use of the training, experience, and technical skills of our profession in military operations rather than to have them scattered indiscriminately through the various branches of service in capacities where their potentialities could not be utilized. We have succeeded in interesting some branches of service in our men, while other branches, in which their training and experience as geologists would be most helpful, seem interested but have done nothing about it as yet; however, we still have hopes and are optimistic enough to believe that this objective can and will be realized. It may be of interest to give you the following information on the classification of members of A.A.P.G. in the Armed Forces of the United States and Allied Nations (from national service committee report) as of February 1, 1943.

CLASSIFICATION OF A.A.P.G. MEMBERS IN ARMED FORCES OF THE UNITED STATES AND ALLIED NATIONS, FEBRUARY 1, 1943

	Privates Cadets Non-Com. Officers Misc.	*Lieuts.*	*Capts.*	*Majors*	*Lieut. Colonels*	*Total*
Army Air Corps	38	59	25	8	2	132
Infantry	26	23	2	3	1	55
Corps of Engineers	14	19	4	5	1	43
Field and Coast Artillery and Anti-Tank	7	27	7	1		42
Armored Force	2	3				5
Signal Corps	3	2				5
Miscellaneous: Military Police, Ordnance, Quartermaster Corps, Military Intelligence	11	10	2	2	1	26
Total Army	101	143	40	19	5	308
Marine Corps	3	5	2			10
Navy—including	*Misc.*	*Ensigns*	*Lieuts.*	*Lieut. Comm.*	*Capts.*	*Total*
Naval Aviation	13	55	38	4	1	111
Coast Guard	1		3			4
Total Armed Forces						433

Note.—The above figures include only those members of A.A.P.G. where we have actual information or records, but do not include many members and non-member geologists who have not notified us of entering military service.

In making an analysis of the distribution and duties of the members of the A.A.P.G. in the Armed Forces, it is quite apparent that the geologists are not in positions where their training and experience as such are being utilized, with the outstanding exception of the Army Air Corps. To the best of our knowledge, the Corps of Engineers, Coast Artillery, Armored Force, Military Intelligence, and other branches of the service have utilized the geologist as a geologist in only a limited number of instances, and it is in these branches of service that his technical skill can be most effective. We hope this condition will change, and we believe that it will. Be that as it may, there is no question that the geologists, wherever they are and regardless of whatever branch of service they are in, will make excellent officers, soldiers, sailors, and marines and will do their utmost to bring victory for us and the Allied Nations.

STATUS OF PETROLEUM GEOLOGISTS IN PETROLEUM INDUSTRY

It will be of interest to everyone to know the situation with respect to our present personnel available for petroleum exploratory and development purposes. The following is an estimate of petroleum geologists, as of February 23, 1943, in the Armed Forces and in civilian capacities with Government agencies connected directly or indirectly with the war effort.

A.A.P.G. members in military service	500
Petroleum geologists (non-members A.A.P.G. in military service)	100
A.A.P.G. members in civilian capacities with Government and Allied Nations	175

A total of 775 are in military and civilian capacities with the Government and Allied Nations. Normally not more than 3,500 petroleum geologists are in the United States, but even considering a figure of 4,000, approximately 20–25 per cent (considering those working as civilians on war problems, *et cetera*) of our personnel are not available for exploratory and development work in the petroleum industry. Some of the geological departments have lost through volunteers and the draft as much as 40 per cent or more of their geological personnel (not including non-geologists). It is not the purpose of this paper to go into any detailed analysis of this situation, but we are faced with the fact that a real and definite manpower shortage of geological and geophysical personnel does *now* exist.

NEED FOR NEW DISCOVERIES

Do you remember but a few years ago how complacent and satisfied the petroleum industry and the public were that we had so much proved reserves—that no situation could arise, not even war, when petroleum needs could not be satisfied by simply turning on a few valves or spigots? Practically all of the petroleum geologists realized that our new discoveries were not sufficient to replace the annual production, but nothing was said about it until a few years ago when E. DeGolyer brought out his remarkable analysis of the actual conditions. Recently, the full purport of this critical situation has been brought very forcibly

to the attention of all concerned by the Office of Petroleum Administration for War and many others who have made a careful and thorough study of the situation. In addition, other factors have entered the picture insofar as the ability to produce the requirements of the war demands of the military, civilian and essential industries is concerned. To quote from E. DeGolyer's paper before the 1943 meeting of the A.I.M.E. on "Petroleum Exploration and Development in Wartime"—"We are not concerned now with this decline of discoveries for effect on reserve position, but are moved by stern need to increase daily productive capacity; and to discover new pools is the quickest and most effective method of achieving such result at minimum expense of manpower and scarce critical materials." DeGolyer, Heroy, and others will appear on this program and will give you a very clear and comprehensive analysis of this critical situation. Petroleum and its products are absolutely essential and of paramount importance in the successful prosecution of this war.

RÔLE OF THE PETROLEUM GEOLOGIST AND GEOPHYSICIST IN EXPLORATION

Since we are accepting the situation as critical in regard to the necessity for the discovery of new petroleum reserves as outlined by the Office of Petroleum Administration for War, as has been so clearly stated by Harold L. Ickes, Ralph Davies, E. DeGolyer, Wm. B. Heroy, and others, then it is not only the patriotic duty of, but a challenge to, our limited number of petroleum geologists and geophysicists to do everything in their power to bring all of their talents, tools, skills, imagination, and resourcefulness into this most important program. Comments on several problems and a few suggestions are offered on the ways and means to assist in increasing our efficiency in that respect.

1. Since so many of our detail and key personnel are not available, the work that they had been doing has been added to the duties of those now having the responsibilities of carrying on. This condition, together with that of spending so much time on consultation, advisory services, war problems, and coöperative duties with Government and State agencies, other added duties, and other factors not involved in the normal course of events, may have placed such a heavy burden on the geologist that it is a handicap to the direction and the work of exploring for oil. We hope that the burden, if it is such, is not too heavy, but even so—it must be borne, regardless of sacrifice. In other words, under all conditions, we are not asking any sacrifices comparable to the man who offers his life for his country.

We do have a very limited number of unemployed geologists who, if properly placed, would assist to some extent in relieving the shortage. Most of these are of middle age or older and are available for temporary or permanent services.

2. You will recall the symposium, conducted last year at the Denver meeting, on "Oil Discovery Methods," by A. I. Levorsen. The most important tools and methods of the petroleum geologist and geophysicist now in use and suggestions as to their more efficient use were discussed in considerable detail. Among the

many tools and methods for exploratory work as discussed were surface, subsurface, local and regional stratigraphic studies, core drilling, slim-hole drilling, stratigraphic traps, and geophysical work such as seismograph, gravity meter, torsion balance, and magnetometer; and coördination and interpretation of all phases of geological and geophysical work. It was the general opinion that no satisfactory new tool or method had been developed or was in sight to increase the efficiency of our present well known methods, and it appeared that our greatest possibilities for more successful results were in the "sharpening" of our present tools. In other words, to take our present ones and improve, refine, and overhaul them. Of the many methods and techniques, the stratigraphic-trap method and ideas, as have been so well presented to us by A. I. Levorsen, and the improvement in the techniques of geophysical prospecting were most prominent. However, there was a trend of thought that the older methods, such as core drilling, stratigraphic studies, surface (including interpretation of aerial photographs) and subsurface work had not been used to their greatest potential possibilities. All in all, it appeared that no one or lone method of prospecting would solve our problem of finding new reserves, but that a combination of coördination and interpretation of all of them has the best possibilities of success. Regardless of any or all methods, we must face the fact that it is becoming more difficult and more expensive to find new oil fields and that it will become necessary to do a large amount of stratigraphic-trap prospecting and random drilling. Any well drilled in a possible oil area, whether it is on a structural prospect or for stratigraphic or other purposes, may be the means of furnishing the desired information for additional drilling and the final discovery of important new reserves. Our laboratories and our specialization in all geological, electrical, and geophysical correlations and techniques have improved and are still improving to such an extent that data of any nature can be analyzed very thoroughly so that the ultimate in information is available.

ADDITIONAL FACTORS INVOLVED IN EXPLORATION ACTIVITIES

1. Tools and methods alone can not accomplish the ultimate in successful exploration for reserves. There are other things to be considered as an aid to the stimulation of exploratory prospecting. The whole history of the petroleum industry is outstanding in that the wildcatter who has the venturesome spirit will do things and drill wells contrary to the advice of the leaders in the industry and many well meaning geologists. Many great oil fields have been discovered by these pioneers—outstanding examples have been E. W. Marland, Tom Slick, Dad Joiner, and scores of others. What did they have that seems to be at least partially lacking to-day? Nerve, courage, faith, optimism, imagination, and perseverance. Some of our executives in the industry, as well as the geologists under their management, have often become discouraged and disheartened by the drilling of one or even several dry holes on a prospect and then given up faith in the whole deal and become soured on that area and the entire district. Later develop-

ments proved that oil fields existed in many of such areas—so that the rewards were collected by those who had the courage and faith to do the impossible. As a good recent example of patience and perseverance, The Pure Oil Company drilled a number of dry holes on a prospect near Pauls Valley in Garvin County, Oklahoma, but, instead of losing faith, they capitalized on the information furnished by each well and added it to that previously obtained—so that finally they "hit the jack-pot" with one of the best discoveries in Oklahoma in recent years.

To be more specific in these applications to the petroleum geologists, and even considering all of our tools and methods, there is still something often lacking in the mental make-up of the exploration geologists. You may call it imagination, ingenuity, resourcefulness, or geological philosophy. In the early days, the petroleum geologist did not always have complete or satisfactory information on which to base a recommendation, but, being resourceful and having an open mind he had no fetters or shackles on his imagination or line of reasoning and would make recommendations which to-day would be considered unorthodox by some. An example is the Tonkawa oil field of Kay County, Oklahoma. It was discovered by a combination of very meager or sketchy geological information such as a few local dips, structural trend, and questionable subsurface information from a few isolated shallow gas wells. Core drilling or seismograph work could have found the field, but the point to be emphasized here is that the same geological philosophy can be used even with our modern methods of prospecting.

Along the same line, there has been a tendency in recent years for the petroleum geologists to divide themselves into two groups, namely, "Liberals" and "Conservatives." The petroleum geologist by reason of his kind of training and experience is a natural "Liberal" who not only uses all of his scientific and technical knowledge, but also takes into consideration all of the speculative and logical deductions involved. The "Liberals" would include most of the independent and company geologists. The "Independents" on the one hand are probably the most extreme in this respect as they are principally interested in drilling wildcat wells and the promotion or selling of blocks of acreage, while the company geologists on the other hand are primarily interested in selling the managements of their companies on the merits of their recommendations. The progress and initiative of their respective companies in the discovery of new oil fields are largely dependent on their ability in this respect. The "Conservatives" are the ones who are never satisfied to make recommendations without exhausting all possible means of checking the possibilities with all geological and geophysical methods before venturing to make a qualifying recommendation. It seems that somewhere in the course of their experience, they have lost most of that perspective so common to most geologists and their speculative and logical reasoning powers have become dwarfed or stunted. Fortunately there are not too many petroleum geologists in the latter class. The suggestion offered here is that the so-called "Conservatives" should become inoculated with some of the characteristics of the "Liberals." It has been the "Liberals" who by their liberal thinking have dis-

covered most of the oil fields accredited to geological information, and it is this group who are willing to, and do, accept the responsibilities for the discovery of new reserves during this emergency.

2. Regardless of the excellent work of the petroleum geologists and geophysicists, it can still be buried and accomplish nothing as far as satisfactory results are concerned unless there is coöperation between them and the management. In the case of the independent geologists, they are dependent on receiving the same cooperation from the company geologists and managements. It is not necessary to go into detail on this subject, as all of you know that the policies of the managements in the different companies are not the same and also that there is a different degree of coöperation in this respect in the different companies. As an extreme case, there are the companies where the geological and geophysical departments are completely submerged into very subordinate positions of influence in connection with exploratory activities. On the other hand, there are many companies in which these departments dominate, not only the exploratory activities, but all others in the development and production of oil. To go a little further, you have noticed that in many of these companies, the petroleum geologists have climbed up through the ranks of administrative to the uppermost and top-ranking executive positions in the petroleum industry and in the Government agencies. The history of the rise of many company petroleum geologists, as well as independent geologists, to positions of affluence would read like some of Horatio Alger's books.

You have probably noticed that in general the successful independents and companies in the exploration for oil are the ones where there is close coöperation between the geological and geophysical work and the managements. The complete coöperation of the other departments of exploration and the managements with the geological and geophysical departments will insure a greater success in the discovery of new petroleum reserves.

3. There is still another suggestion that seems to offer possibilities in our assistance to the program of discovery of new petroleum reserves. Most of the industries have unlocked their hoarded caches of secret information on patents and all other things that they have guarded very zealously during normal peace times. Now, during the war, they have voluntarily pooled everything necessary for the benefit of the Nation in the prosecution of the war. The petroleum industry has done likewise in practically all phases of its activities, but there is still room for an all-out participation in a few other phases. All of us know how the geological and geophysical information of the different companies is guarded under lock and key and also that the most secret information is imparted to only a few in such organizations. This is not a new method of doing business, as it has been the same for many years. The petroleum geologists and geophysicists are just as much responsible for this situation as the managements. What would be good business practice in normal peace times may not be the same or for the best interests of our country in the prosecution of the war, since we know that petroleum and its products and discovery of new reserves are vitally important.

To make a direct application of the foregoing statement, let us assume that individuals or companies have limited or unlimited geological and geophysical information on certain prospective areas and that they will explore these prospects in the very near future so that the practical results of condemnation or discovery will be accomplished without divulging the so-called secret information. Yet there are many examples where this would not secure the best results in the interest of new discoveries. You are not being urged to reveal all of your information on districts and states, or even on local areas except to interested parties having lease ownership. All of you know that there are many prospects where lease ownership is diversified to such an extent that no one company or individual would be justified in exploring without assistance. It is in these localized known prospects that the exploration efforts need to be stimulated and the geologists and geophysicists can do more than any one else in this respect, if permitted to pool or communitize all of their information and if such pooling of information is restricted to the benefit of the participants. Many examples can be cited where as many as eight or ten companies have protective acreage and all of them have their own geological and geophysical information. If all such information were pooled and thoroughly discussed by the interested geologists and geophysicists and recommendations made to their respective companies, there is a greater probability that the managements would be favorably interested in following through with unitization and prospecting. Then, again, with as complete information as possible, better discovery locations can be made and thus the average ratio of discovery wells to total number of wildcat wells drilled could be reduced. Please note that these suggestions are made with respect to local areas only; however, if the need arises and the emergency becomes sufficiently grave insofar as the petroleum requirements are concerned, then there should be no limit to the regimentation or pooling of geological and geophysical information and personnel.

SUMMARY

In the history of the application of geology to economic and industrial enterprises the petroleum geologist has made not only a fine record for his scientific accomplishments, but also an outstanding one for his ingenuity, aggressiveness, and resourcefulness—a record hardly paralleled by any other profession. He has not only been able to establish himself as an important factor in the discovery of petroleum reserves, but he has had the satisfaction of seeing his abilities for administrative and executive positions recognized by the petroleum industry—a situation slow in developing, but recently increasing to a very marked degree.

The critical need for new petroleum reserves resulting from the demands of increased civilian, industrial, and war operations, and the increase in the discovery rate of new reserves to insure an adequate and unquestionably ample supply for all purposes, are among the paramount and most serious problems facing our country and other Allied Nations. The petroleum geologists and geophysicists have the most important rôles in the successful fulfillment of this program. There

is no question that they will do their utmost in every way to coöperate, even though they may be working under a serious handicap of shortage of manpower and other obstacles. We are firm in our belief that we have the tools, methods, and many other requirements necessary to carry out this program, provided complete coöperation is given and no further serious inroads are made in the necessary manpower and personnel. Even then, the road will be rough and rocky and all of us will be required to use every resource at our command—so let us extend ourselves in using all our skills and methods and, equally as important, let us get the brain cells thinking and "clicking"—and, not least by any manner of means,—"*Let's go to work!*"

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ECONOMIC PALEONTOLOGY AND MINERALOGY—AN APPRAISAL[1]

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ABSTRACT

The demands for oil and efficient use of manpower serve as a challenge to everyone connected with the oil profession to aid in obtaining the most oil with the least amount of lost effort. Coöperation is paramount and requires an understanding of the activities of co-workers in allied sciences. Accordingly, this paper presents the economic aspects of paleontology and petrology, answers some of the common questions and comments directed to these laboratory workers, and offers suggestions toward more efficient use of data and training derived from these sciences.

INTRODUCTION

The fact that the American Association of Petroleum Geologists, its technical division the Society of Economic Paleontologists and Mineralogists, and its affiliate the Society of Exploration Geophysicists are among the few organizations that have been permitted to hold a convention during these war times is one of the most convincing proofs of recognition of the economic value of petroleum geology and its branches. This privilege and recognition carry with them appreciable responsibilities. Are we properly guiding our activities to aid in finding the greatest amount of oil with the least amount of lost effort? Each of us should consider this question, for the need for oil and the efficient use of manpower are imperative. Information recently released by Harold L. Ickes, in his capacity as Petroleum Administrator for War, shows that a conservative estimate of new discoveries of oil made during 1942 amounts to 421,128,000 barrels and that a maximum estimate amounts to 800,859,000 barrels. These new reserves would replace only about 30 or 57 per cent, respectively, of the approximately 1,400,000,000 barrels of oil actually consumed during 1942. During that year, the need for more oil reserves was thoroughly recognized and the use of petroleum products was limited largely to defensive warfare. Now that greater activity by the Allies in offense is under way, there is even greater need of additional reserves of oil. It is up to us as petroleum geologists to successfully cope with this emergency. Our first concern should be to adequately acquaint fellow geologists with the limitations and advantages inherent in our special branches of geology, so that the combined knowledge of geologic science may be efficiently applied toward the finding of new oil reserves. Teamwork is needed now as never before. This appraisal of economic paleontology and mineralogy is made in accord with that primary objective. Only those details necessary to furnish information concerning

[1] Sixteenth annual address of the president of the Society of Economic Paleontologists and Mineralogists before the joint meeting of the American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, and the Society of Exploration Geophysicists at Fort Worth, April 8, 1943. Manuscript received, April 8, 1943. Published by permission of the Standard Oil Company of California.

[2] Standard Oil Company of California.

the basis for the work will be discussed. More complete data may be obtained by consulting the publications cited and their accompanying references.

Unfortunately, many laymen, some of our fellow geologists, and even a few paleontologists fail to evaluate properly at least phases of the work conducted by economic paleontologists and mineralogists. In some cases, information reported as estimated data is accepted as definite by other than laboratory workers because of previous favorable experience in the use of laboratory data from areas more suited to such correlation. In other cases, definite laboratory data are questioned. Varying factors affecting the deposition of sediments and their organic content result in correlations having varying degrees of probability, thus showing paleontology and mineralogy to be legitimate branches of the inexact science of geology. Largely because of the inexact nature of these branches of geology, there is even greater need than in more exact sciences for anyone applying these data to economic problems to depend on experience and training.

DEVELOPMENT OF APPLIED PALEONTOLOGY AND MINERALOGY

The application of paleontology to economic work was gradual prior to its use in the oil industry. Paleontology deals with fossils, which by definition are any evidence of the former existence of organisms, either plant or animal. Differences between plants and animals are commonly considered to be conspicuous, but the distinction may be indefinite when single-celled organisms are considered. The earliest record of applied paleontology is that by William Smith (1769–1838), who made observations of fossils during his work as a construction engineer. A little later, records show successful application of paleontology to the mining industry. Historical outlines of the use of paleontology have been published by Hubert G. Schenck, "Applied Paleontology," and by Carey Croneis, "Micropaleontology—Past and Future," in the *Bulletin* of the American Association of Petroleum Geologists, Volume 24, Number 10 (1940), and Volume 25, Number 7 (1941), respectively. The first record of examination for foraminifers from a well in North America is attributed to Frederick Chapman, who, in 1897, obtained cuttings from a well in Santa Clara County, California. In 1918, the Rio Bravo Oil Company, and soon afterward the Humble Oil Company, established, in Texas, the first laboratories to apply paleontology to the oil industry. Within a few years most of the large oil companies had paleontologic laboratories. Many of the small oil companies avail themselves of the services of consultants or furnish samples to oil companies which maintain laboratories, in order to obtain paleontologic data. The number employed on the staffs of these laboratories has varied largely according to the demand for oil. The work has been shown to be sufficiently essential that with very few exceptions a laboratory once established has been retained in operation. The establishment of paleontologic laboratories in foreign operations progressed as the value of the work in local laboratories became recognized. Foreign expansion of this work was continuing until the present war activities caused suspension of geologic work in many of these countries.

Economic application of mineral grains dates from earliest mining activity. The systematic study of minerals has been stimulated by application to problems of correlation in the oil industry. Mineral-grain investigations usually are carried on in conjunction with the study of fossils in paleontologic laboratories.

The rate of application of paleontology and mineralogy to the oil industry is reflected by the publications sponsored by the Society of Economic Paleontologists and Mineralogists. The first issue of the publication of this society, the *Journal of Paleontology*, was issued in July, 1927, and circulated to 80 charter members. Since 1934, the publication has been under joint sponsorship with the Paleontological Society. A peak of 938 subscribers was reached in 1939. The decline to the present 847 subscribers is largely because of the loss of foreign subscriptions during the war. Papers pertaining to mineralogy also were published in the *Journal of Paleontology* until May, 1931, when the first issue of the *Journal of Sedimentary Petrology* appeared. This publication also is sponsored by the Society of Economic Paleontologists and Mineralogists, and now has about 385 subscribers. Both of these publications have attained a place of eminence in their respective fields.

Paleontologic literature, especially that pertaining to micro-organisms, has flourished because of the economic application of data derived from fossils. Literature dealing with foraminifers is an example. Prior to 1911, there were about 3,900 titles of such publications. From 1911 to 1931, inclusive, about 1,200 articles pertaining to foraminifers were published. From 1932 to 1939, inclusive, Hans E. Thalmann has recorded in annual bibliographies published in the *Journal of Paleontology*, references to over 2,700 publications dealing with these micro-organisms. Even the classification of foraminifers has been altered toward more limited divisions since the application of paleontology to the oil industry. Only 10 families were recognized even as late as the publication by J. A. Cushman, "An Introduction to the Morphology and Classification of the Foraminifera" (July, 1925). Editions of his text, *Foraminifera, Their Classification and Economic Use*, published in 1928, 1933, and 1940, show the number of families into which these organisms have been grouped to increase from 45, 47, and 48, respectively. Largely because of their value in economic applications, foraminiferal data have been catalogued by Brooks F. Ellis and A. R. Messina and published, starting in 1940, by the American Museum of Natural History. The set now comprises about 30,500 pages, which include approximately 1,500 generic names and over 18,000 specific designations.

STRATIGRAPHIC SIGNIFICANCE

The statement that present geologic phenomena portray the past may be viewed with reasonable assurance. The action of weathering and of forces of tension and compression on rocks, the effect of wind, streams, and currents on sediments, and the effect of depth, temperature, and salinity of water on organisms apparently had similar results in the past as at present. Accordingly, fossils which

are related to living organisms characteristic of stream, lake, estuary, or marine deposits are probably indicative of sediments of corresponding character which were deposited in past time. Likewise, a similar relationship may be expected in petrologic character. Recent marine organisms characteristic of various depths, temperatures, and types of deposits have ancestors which probably had at least roughly corresponding habitats during earlier times. Plants and animals vary in size, from trees and large animals to organisms so small that a microscope is required to study even complete specimens. They also vary from complex forms represented by recent trees and vertebrates to simple single-celled organisms such as diatoms and foraminifers.

Oceanographic expeditions and related research work have furnished most of our knowledge of marine sediments and of recent marine organisms. The British Expedition of H.M.S. *Challenger* during the years from 1873 to 1876 was one of the most extensive. The relationship of a yacht trip to production of oil may not be very apparent. Nevertheless, several expeditions and research problems have been partially financed by oil companies, to the mutual advantage of geologic science and the oil industry. Through these investigations we have learned that foraminifers are usually associated with fine sediments, for neither they nor the smaller organisms which constitute their food supply can withstand rapid currents. The larger snails and clams usually thrive in the sands which are deposited in more rapidly moving water between highest and low tides. Dwarfing of organisms is an indication of their struggle for existence. Both plants and animals may be free swimmers or bottom living forms. Some organisms may be free swimmers only in the early stages of their lives. A few animals thrive at depths in excess of 6,000 feet. Aquatic plants live only in shallow water, for they require sunlight, which is limited to an effective penetration of about 180 feet in ocean water. The tendency toward uniformity in sediments and organic assemblages may be interrupted locally by such factors as tides, upwelling of deep water, change in rate or source of deposition, submarine slides, or by ocean currents. Reworking of sediments frequently results in mixed fossil and mineral assemblages. Details of the sedimentary processes involved may be obtained by consulting a standard text such as *Principles of Sedimentation*, by W. H. Twenhofel.

Dating of strata by means of paleontology is based on the tendency of older rocks to contain a progressive increase in primitive fossils and a progressive decrease in specimens related to recent forms. Some paleontologists were slow to realize that even single-celled organisms may be sufficiently changed through evolution to be of use as indicators of age. The multicelled vertebrates and molluscs have been most thoroughly studied for chronologic data.

No one group of organisms or petrologic characteristics is adequate to furnish all the stratigraphic data that may be obtainable. Micro-organisms are of value because of their widespread distribution, abundance and small size, a feature which permits many complete specimens to reach the surface even from well cuttings. Foraminifers are the most generally used of micro-organisms because of their

universal occurrence and abundance in many different habitats. Paleontologic data may be made more complete and reliable if the data derived from both large and small fossils are related. Correlation of similar organic assemblages frequently are comparisons of environment. For example, recent brackish-water organisms are limited to a comparatively few forms which seldom can be differentiated from fossil assemblages occurring in rocks of various ages. Also, two deep-water faunal assemblages of different ages frequently have more species in common than deep- and shallow-water faunas of the same age. Detailed study is usually necessary to differentiate chronologic divisions in an uninterrupted series of sediments.

ECONOMIC APPLICATION

"What has all this to do with barrels of oil?" There is a very direct relationship between organisms, sediments, and oil. Under suitable conditions of burial and alteration, organisms furnish the source of oil and, along with minerals, serve as guides to its accumulation. Oil may migrate into any rocks which have sufficient porosity and permeability, such as sands, cavernous limestone, fractured shale, and even vesicular or weathered igneous rock. Oil tends to reach the surface unless trapped by some impervious material. If trapped, oil will be held in the interstices of the reservoir rocks. The most common types of traps are folded impervious rocks which dip downward around reservoir rocks forming a domed structure, faulted reservoir rocks which are sealed updip by gouge or by juxtaposition with impervious rocks, lateral sedimentary changes from reservoir rocks to impervious rocks in updip direction, and impervious beds deposited across truncated reservoir rocks. All methods used in the search for oil have as their objective the locating of structural traps which may contain oil.

The basis for the application of paleontology and mineralogy is largely that of matching assemblages or species from adjacent localities in order to trace beds between the localities sampled. These data are assembled from samples collected at surface outcrops and from wells. Samples from wells are commonly obtained from cuttings circulated to the surface during drilling or from sections of rock in the form of cores. Only first occurrences of species and variations in their abundance need to be considered from well cuttings, for the assemblages may contain any species present in strata previously penetrated. Cores permit comparisons of assemblages so that similar environments may be correlated. Structural maps are prepared from these data by recording on a map the depth in reference to sea-level at which a particular organic occurrence or bed is reached in each well sampled. Lines showing the positions of common depths to this datum then are drawn, and from their configuration, the type of trap, and the most favorable location for drilling may be determined. Two or more datums may be chosen in each well and a map made having lines which indicate a uniform interval between any two correlative positions. Such a map permits the location of former shore lines, thus indicating one of the possible traps for oil. The accuracy of these maps is dependent largely on the number of locations at which correlative positions may be de-

termined. In some cases, wells have been drilled solely to obtain additional infor mation. The cost of drilling a well which fails to reach oil is not entirely lost if adequate observations and records are made.

The purpose of correlation by means of organisms and minerals involves problems of geology, engineering, and economics. In addition to aiding in the location of subsurface traps, results of the work are furnished to field geologists to identity the age of outcropping strata and to indicate the continuity of beds which could not be definitely mapped because of interruption resulting from faulting, masking by intervening overlying material, or changes in sedimentation. The sequence in changes of organic and mineral species may be determined from surface outcrops, thus permitting a section to be made from which the total depth of a well contemplated to be drilled near by, as well as casing and coring programs, may be estimated prior to drilling. Examination of samples from the well during drilling permits a check of these estimates to be made. Evidence may be furnished prior to running an electric log, that the well has reached a desired stratigraphic position, thus assuring that all the interval may be included without the need of making an additional run. The identification of shale overlying water sand permits completion of a well before bottom water is reached. These data aid further in the efficient development of oil zones by determining the proper stratigraphic interval to open to production in order to avoid inclusion of excessive amounts of gas or water. They also aid in the determination of adequate well-spacing patterns and in problems pertaining to oil-field valuation.

Minerals are used to identify rocks and to match assemblages. The importance is apparent of differentiating basement rock from sedimentary rock and from intrusive igneous rocks below which oil may occur. Ash beds may make excellent stratigraphic markers, for commonly they are widespread and of limited vertical extent. Matching of mineral assemblages involves comparison of specific mineral identifications, abundance of each, color, crystalline character, grain size, degree of angularity and sorting, and character of induration and preservation. These investigations commonly require screen analyses and examination by means of a petrographic microscope. In addition to the value of rocks for their mineral content, their examination aids in the determination of suitable cap and reservoir rocks, direction toward former shore lines, and, most important, whether oil is present. As shore lines are approached, the sediments commonly become coarser in texture and more irregularly deposited, so correlation by petrologic means becomes more uncertain, whether recorded from direct observation or by electrical methods. Lithologic units may cut across chronologic divisions.

The first requisite in correlation by means of fossils is the presence of identifiable organisms. Another requirement is suitable material for comparison. Identical procedure has not been noted in any two laboratories. Such variable factors as the character of training and number of personnel on the staff, laboratory facilities, character of material, number of samples to be examined each day, availability of supplementary data, and nature of reports desired, result in methods which are

well suited to one set of conditions but may be unsuitable under different conditions. A few general procedures are universally applicable. Collecting of samples is one of the most important steps in the entire procedure. This work should be done by some one thoroughly familiar with the proper selection of suitable material and capable of making appropriate notes. If crushed or fragile fossils, including micro-organisms, are present they should be identified as closely as possible while in the matrix. Care to avoid contamination and excessive destruction of micro-organisms must to taken during preparation of samples. Records including relative abundance of the entire organic content of each core and surface sample are desirable. These records, made by listing or mounting specimens, permit study of gradual changes in environment and of limited occurrences of rare forms which may have stratigraphic importance. Graphically prepared charts showing ranges of species in critical sections are valuable aids in correlation. Attempts are usually made to secure on a laboratory staff, specialists in the branches of work most frequently involved by the samples submitted to that laboratory. The workers from some laboratories take one sample for each 3-foot tray of core, and from other laboratories may take composite samples up to the full length of each core, provided the material is similar. Samples from short intervals may permit closer correlation, but it is questionable if the additional work is warranted, especially when the top or bottom of a core is so frequently subject to question. In special instances the top of a core may be determined by organic content, but in general it is more practical to look for the position of the core catcher, rhythmic sedimentation, scouring effect, or the position of plano-convex organisms, such as sand-dollars, which commonly lie with their flat side downward.

QUESTIONS AND ANSWERS

The following are answers to some of the questions and comments with which laboratory workers have been confronted.

"What oil fields have been discovered by the use of organisms?" Statistics have been published listing methods of discovery for various fields, but in most cases these data are misleading. Although no mention may be made of organisms, most geologic reports and maps deal with chronologic units which are based on paleontologic evidence. The discovery of an oil field is the result of successful co-operation between so many individuals and methods that seldom can any one properly be credited. The nearest approach to an exception is the method whereby geophysical data may be obtained below masked or unconformable surface beds. Even under these conditions gross inefficiency would be involved if other usual aids to the discovery of oil were neglected during wildcat operations.

"What features are commonly inherent in the use of geophysical methods, electric logs, and paleontology and petrology?" Geophysical methods may determine subsurface structure which is not reflected at the surface and may aid to determine the proper configuration of contours between correlative positions established in a limited number of wells.

Electric logs have the avantage of indicating a continous record of data from which may be inferred the location of beds of various texture and permeability and positions of salt water or either oil or fresh water.

Cores establish the character of the electric-log variations, may contain assemblages of fossils and minerals which aid in correlation, furnish a means of determining attitude of bedding, and permit observation of fault zone phenomena if present. Fossils furnish the most practical means of dating strata in commercial work. Surface samples supply data similar to data from cores and enable large fossils to be used to greater advantage.

"If the contact between Miocene and Pliocene can not be definitely determined how can reliable zonal divisions be made in either epoch?" When sediments from these or other epochs are brought into contact after an appreciable interruption in sedimentary sequence, the character of the sediments and their fossil content are usually sufficiently different so that the rocks often may be differentiated about as readily as the red central portion of a ripe watermelon can be differentiated from its green outer surface. If continuous deposition is present at the locality being examined, the definite position of difference between epochs may be as difficult to choose as the exact position of change from the green rind to the red central portion within the watermelon. The positions chosen by different laboratory workers may not be identical but the differences are merely matters of nomenclature if the determinations at each laboratory are consistent. The limits of formations are commonly mapped by field geologists, and paleontologists have to make the best of it. Zonal divisions within formations are usually based on assemblage differences selected by laboratory workers.

An example of what was considered to be inefficiency was cited because 15 men sampled the same series of cores and then returned to their laboratories to look through a microscope at the material, not with one eye but with two. Times have changed in the year since that comment was made, for some of those 15 probably now would be women. The value of information from cores is largely dependent upon samples and observations being obtained in accord with procedure established by each company desiring that data. Laboratory workers have to avail themselves of obtaining samples when they are available. Two workers are usually sent from each laboratory if, thereby, a second trip may be avoided.

The use of two eyes permits stereoscopic effect, which is of advantage in the identification of globose objects. There need be no more hesitancy to use two eyes to look through a microscope than to look through reading glasses.

"Why are such complicated names applied to organisms?" The binomial system of nomenclature now in use was devised by Linnaeus in 1735. Under this system the first name applies to the genus, a group designation for related species. The second name refers to the species and is often a descriptive term. Many of the names are derived from Greek or Latin. An additional name may appear which would refer to a variety. The names of the authors of the species and the variety appear after the respective names. As soon as a new species or variety

is published, its identity is universally available. Letters or numbers frequently are used to designate new forms in commercial laboratories, at least until the proper designation can be obtained. Such a system is practical only until information gained by others outside of that laboratory is desired. One field geologist reported that he had found a zone of snake teeth, and so designated the bed. The fact that the fossils are more generally known as *Dentalium pretiosum* Nuttall and have nothing to do with snakes was apparently of no concern.

"What training is desired of an applicant at a micropaleontology laboratory?" No doubt the answer to this question would vary with the demands at each laboratory. If the applicant has a thorough four-year course in geology and an interest in paleontology, there are several phases of the work which he would be capable of doing. He would also be in position to fit into other geologic work, and his laboratory experience would be of mutual benefit. If he desires to specialize in paleontology, five years or more of university work are advised, with training in the basic principles of paleontology, including courses in invertebrates and foraminifers. Detailed study of laboratory methods is not of great advantage, for methods vary with operating conditions. Courses in petrology, petrography, biology, other micro-organisms and vertebrates are recommended.

PROMOTION OF EFFICIENT APPLICATION

Teamwork between oil companies has become more manifest, especially since the war emergency. The need for oil has made it necessary to drill wells at locations previously considered to be too uncertain of production to be of interest to any one company. Some of these locations now are being drilled by two or more companies who proportion the costs of the well involved and pool geologic data pertaining to its location. Upon completion of a well, it is now common practice to make all cores available for description and sampling by each company interested. Sample-splitting services operate in some areas by collecting and distributing samples of well cuttings to each participating oil company.

Through coöperation between universities and the oil industry the supply and demand for trained men has been reasonably well balanced. Various scholarships have been bestowed by oil companies. Selected men have been granted leaves from commercial activities to carry on academic work. Some professors have had opportunities to gain economic viewpoints by employment in the oil industry during summer vacations. Collections of samples have been supplied to universities for student use. Professors frequently aid in the identification of fossils which are unknown to the staff of a commercial laboratory. Universities make available the results of research problems, distribute geologic data in published form, and grant access to museum collections of identified fossils.

The multiplicity of activities carried on by oil companies has resulted in the organization within each company of various departments, divisions, and groups, with separate functions assigned to each. For example, paleontologists have work allied with that of geologic scouts, field geologists, subsurface geologists, geo-

physicists, various branches of petroleum engineering, and land and lease work. Each group attacks a problem from a somewhat different viewpoint. Through coördination, results are obtained with greater efficiency and reliability than would be possible with independent efforts. After organic sequences have been established there is little need of paleontologic data in areas where structural conditions are known, for electric logs may be relied upon. Many correlations are made more reliable without a great increase in cost by supplementing electric-log data with bedding and organic information obtained from a few cores. The need for data from cores and cuttings increases as correlation and oil-reservoir conditions become more uncertain. Complications in areal mapping likewise increase the need of paleontologic data.

The efficient application of paleontology to economic work has been a problem of concern to each laboratory worker. Early correlations commonly dealt with rather major units of the geologic column. As work progressed, correlations have been made in greater detail. In many cases some of the earlier work had to be reviewed and at the same time current work continued in more detailed manner. Much of this has been accomplished without corresponding increase in paleontologic staffs by standardizing procedure as much as possible. One day in the field usually permits a paleontologist to collect enough samples to keep him busy in the laboratory for several days. As a result, there has been an increasing tendency for paleontologists to make fewer field trips, do more routine microscope work, and depend more and more on acquainting others with their findings, either verbally or by brief notes. This is a tendency which is contrary to effective results. Almost without exception, microscope workers in commercial laboratories are graduate geologists and many hold advanced degrees. We are favored with facilities and are trained to see more in rocks than others who are not so equipped. These details can not be adequately related to practical problems by sitting in an office. Neither can paleontologic and petrologic relationships be adequately considered by others if they are not properly presented. We have reason to be proud of our work, but the tasks are not complete until our interpretations are presented in a practical manner.

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MAINTAINING AN ADEQUATE LEVEL OF GEOPHYSICAL EXPLORATION[1]

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At the time of the Denver meeting last year, many geologists and geophysicists were frankly in doubt as to where their duty lay in the war effort. This year there should be much less uncertainty as we have been given a task on the home front which will tax our resources to the utmost. The task is to locate 4,500 wildcat wells so judiciously that neither steel nor manpower will be wasted in unjustified drilling. The facts which seem to make necessary this enormous wildcat drilling program in the face of a national shortage of critical materials and manpower have been widely publicized in the trade journals, and I shall only briefly recapitulate them.

In 1942 we consumed about one billion, 385 million barrels of oil. P.A.W. statisticians tell us that in this same period and at a conservative estimate, we found 317 millon barrels of new oil in new fields; on the most liberal estimating basis, including new zones in old fields, they are willing to raise the figure to 801 million; one well informed trade journal estimates discoveries at 323 million barrels for new fields, and, finally, the A.P.I. places the figures at 260 million. Personally, I am inclined to accept the highest of these estimates, namely, 801 million barrels given by P.A.W., as being the most probable measure of oil found in new fields and zones last year. However, such estimates of petroleum reserves made in the past have proved to be very inexact and subject to influence by the philosophical basis of the computations; furthermore, we are not justified in equating discoveries made during any one year with exploration during that year since there is a lag varying from months to years between exploration and drilling. There is, therefore, plenty of room for differences in individual opinion, and statisticians can so present the figures as to support widely different contentions. Probably the safest course is to study the trend of estimates made periodically on the same basis. Published estimates which extend back a number of years suggest that the yearly discovery rate of new oil in new fields has been declining for the past 5 years at least. It is a reasonable assertion that some time in the not distant past, consumption exceeded the finding rate of ultimately recoverable oil in new fields for the first time in our history as a major industry; whether this happened as recently as last year, or as long ago as 1939, is probably uncertain. What is more important, not only has the tide of discovery turned, but the ebb is now felt to be running very fast.

[1] Address of the president of the Society of Exploration Geophysicists before the joint meeting of the American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, and the Society of Exploration Geophysicists, at Fort Worth, April 8, 1943. Manusctipt received, May 12, 1943. Reprinted by permission, from *Geophysics*, Vol. 8, No. 3 (July, 1943).

[2] Shell Oil Company, Incorporated.

We are told that no prudent appraisal of the present reserve situation can tolerate a substantial decrease in available reserves, particularly in certain strategic localities, and that the additional oil which will become available by extensions to known pools is inadequate. Our mandate is to discover new fields, even at the expense of a program of wildcatting exceeding the lushest years, and it is one principal purpose of our annual meeting this year to lay plans for so doing.

What methods to use in locating the wildcats which will bring in these new pools is debatable. Lahee[3], in his helpful annual compilation of comparative ratios of discovery by various methods, gives geophysics first place, with geology a good second, and wildcatting a very poor third. These ratings are on the basis of the number of successful wildcats located by various methods as against those which were dry. Were these statistics amplified and re-analyzed to disclose the barrels of oil discovered by the various methods, they would furnish a direct guide as to the best present course. Unfortunately, there does not seem to be a more recent study than that made by J. B. Eby,[4] which extends only through 1938. Statistics taken from Lahee's tabulation suggest that wildcatting without geological or geophysical guidance was relatively unsuccessful, in that during the past 5 years three times as many wells were drilled to discover each producer as was the case under technical guidance. If we go back a few more years and put our appraisal on the basis of barrels of oil found per well drilled, not forgetting East Texas, Slaughter, and several other large low-relief fields, then the wildcatter might, and I believe does, show up to much better advantage. Nevertheless, in planning an exploration program which must achieve a certain minimum objective with reasonable assurance of success, it would be foolhardy to count on the discovery of such reserves by promiscuous wildcatting since the outcome is so largely a matter of chance.

Therefore, it seems wise to plan our exploration program along more predictable lines which will virtually assure the attainment of the minimum objective, and yet not preclude the spectacular results which in the past have so frequently rewarded those willing to take the maximum chances. Geophysics offers the best means, in most areas, of reducing structural uncertainties and so should figure prominently in the program. Let us now consider the prospects of the geophysical branch of exploration being able to maintain its high contribution to successful wildcatting.

In the first place, it is pertinent to review geophysical operations during the past year, both as regards scale and geographical distribution. My figures show that throughout 1942 an average of 225 seismograph crews and 50 gravity crews operated. There was also an assortment of "doodle bugs" which we will ignore for the purpose of this discussion. By far the greater part of these exploration facilities was concentrated in venerable areas of proved production. The backwoods of the presently unproductive areas attracted little exploration.

[3] Frederic H. Lahee, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 6 (June, 1942), p. 977.

[4] "Petroleum and Natural Gas Production," *W.P.A. (National Research Project) Rept. E-10* (July, 1939). Statistical Appendix, p. 337.

Thus, with what approaches an all-time high in scale of operation and a geographic and philosophic distribution of effort closely paralleling that followed in more successful years, we failed to achieve our goal of balancing discoveries against withdrawals; failed miserably by most figures, and failed badly even if the year's results are most optimistically appraised. This picture is made darker by the generally accepted belief that our backlog of good, untested structural prospects in recognized oil territory is being rapidly exhausted.

To meet the present emergency there are four general ways in which we might utilize our geophysical exploration facilities.

In the first place, we could apply our existing techniques with even greater microscopic precision in the already well explored "golden lanes" of productive territory. Continual improvement in seismic methods has resulted in our ability to map accurately, at a cost, the smallest geological features which offer promise of being commercial structural type accumulations; so much of our effort has been directed along this avenue that the natural result is now evident in the statistics—an increased number of discoveries is being made but the size of each individual field is small. We have such wide experience and complete statistics in operations of this type that the results of a further program can be estimated in advance, even to the point of hazarding a guess as to the cost of each barrel of oil *in situ* which will be found by such methods; including the cost of leases and exploratory dry holes, the figure will fall not far from 30 cents per barrel on a steeply rising curve. The law of diminishing returns has overtaken this "gleaning" phase in mature producing areas, and it is to be hoped that our imagination is not so atrophied or our resources so exhausted that we will long be satisfied with it. However, if the necessary facilities are available, and we have to meet a comparatively small objective of discovery, the method has the virtue of furnishing predictable results.

In the second place, we could take our proved methods of structural mapping to new territories as yet inadequately explored, either as regards their structure or stratigraphy. In operations of this type we must take the chance of finding that sediments now pronounced as lacking source beds or porosity, or both, turn up a Yates or a Tinsley. We can not hope to estimate in advance a profitability factor—we may even be totally unsuccessful, but at least in this approach we are playing for high stakes in the best traditions in the industry we serve. The symposium to be conducted by the A.A.P.G. as a part of this program should bring to our attention many such areas.

As a third course, we can again match our technical abilities against the unsolved problems of the geophysically "tough" areas where extensive wildcatting only awaits adequate structural guidance. The problems to be faced in these areas are largely superficial, occasioned by the outcrop of limestone, the presence of caliche, or thick gravel deposits. Southern Mississippi, a notoriously recalcitrant area, does not qualify under any of these descriptions, and presents an interesting problem which has not yet been completely solved. Such areas have been largely

avoided as long as others offering greater ease of mapping remained partially unexplored; as the more easily mapped territories are exhausted, the incentive grows to direct effort to the more difficult. The challenge presented by the "tough" areas has been taken up and I believe the technical resources of the industry are such that, in most such areas, the outcome is not in doubt.

And, fourthly, we can look to new methods to revitalize exploration. The history of geophysical exploration is a succession of surges in activity as new methods or techniques found favor, and each surge initiated a new bulge in the discovery rates. In my opinion, there is no prospect of a powerful new method being brought to immediate commercial success, and I am convinced that the present emergency must be met with the conventional tools already familiar to us, correctly applied, however, in the proper places; we would be foolish indeed to look to any new methods now visible on the horizon to solve our urgent problems for us the easy way.

No conceivable policy of exploration can, with a lesser effort than was made in 1942, offer reasonable assurance of maintaining the discovery rate of new oil. Of course, we might be the beneficiary of a windfall such as a second East Texas, and spectacular results might reward pioneering in new territory, but we can not allow our reserves of petroleum, the most critical of all war materials, to be dependent entirely upon the outcome of any such gamble. It is my belief that to meet the immediate emergency we should persevere in the humdrum mapping of small structures in proved areas with the greater part of our available facilities. Nevertheless, it is to be earnestly hoped that enough facilities will remain to make possible a much expanded program in outstepping and poorly explored areas, as only in this way, I believe, can the creeping paralysis which has beset discovery be stayed. Furthermore, we have the Petroleum Administrator's announced objective of 4,500 wildcat wells this year to face. If this objective is to be even approached a high discovery rate of new prospects must be maintained as the backlog is on the way to exhaustion. Even so, many wells must be drilled to test prospects other than conventional closed structural traps in present productive areas; in the oil country there are nowhere near that number of structural prospects known and untested. Such an abundance of wildcats, if it proves economically possible to drill them, should insure the testing of virtually all our structural prospects and of many stratigraphic traps and yet leave enough over to follow up exploration in new areas. Nothing in the present situation justifies a belief that the contribution of geophysical oil can be maintained with less facilities than we had last year; what are the chances of our keeping these facilities intact?

Our success in keeping a full complement of crews in the field during 1942 despite the drain of personnel to the army and war industry may have created a feeling of false security concerning our ability to continue doing so. B. B. Weatherby, chairman of the war efforts advisory committee of the Society of Exploration Geophysicists, has assembled and analyzed figures bearing on the loss of personnel by geophysical operators, and I am indebted to him for most of the statistics used

in this discussion. The total number of technically trained men employed in geophysics is not more than 2,000 and the total complement of men, skilled and semi-skilled, in the industry does not exceed 5,000. Of our technically trained staff, 40 per cent has been lost to the armed forces and to war work. Only the farsighted policy which had maintained technical men two-deep in nearly all key posts throughout our pre-war organizations permitted the continuation of operations on the former scale despite this loss of men. We are now down to the first-string team with virtually no reserves, and further losses of technical men will inevitably mean the shutting-down of field crews. The seriousness of this situation can not be exaggerated since a complete shutdown of seismograph exploration could be brought about by the removal of 500 men. The position as regards semi-skilled workers is even worse. Statistics which cover more than 80 per cent of geophysical operations for 1942 disclose that 1,428 men out of a total payroll of 4,370, went into the services and 1,974 into other industries—during the same period, 3,252 replacements were hired, representing a turnover of 75 per cent. In such a highly specialized type of operations, efficiency has naturally suffered; furthermore, the trend of the times may be indicated by the fact that at least four operators have already reduced the number of their crews in the field.

Second only in importance to manpower, is the problem of obtaining the supplies we need. A study of the consumption of critical materials in our operations is illuminating. Our total consumption of dynamite for 1942 was about 5,000 tons, which represents somewhat more than 2 per cent of the industrial consumption of the United States. The manufacturers assure us that this comparatively small consumption has no effect on production for war, which is carried on in separate plants and involves a different type of product. Our consumption of steel is even more relatively insignificant. Shot-hole casing is the largest single item, and, according to my own estimate, it amounted only to 10,000 tons last year, of which most comprised discarded material of a type not in demand as scrap. Transportation probably constitutes our greatest drain on critical materials. The geophysical industry is operating 2,000 motor vehicles under unusually severe service conditions, and it is very difficult to see how we could substantially reduce this number.

It is the consensus among geophysical operators that the loss of trained personnel is our most serious problem. The particular type of training common in the ranks of geophysical organizations finds ready acceptance in many technical branches of the armed forces and also in war industry and research. Our ranks have been subjected to assaults from all these quarters and casualties have been high. To offset losses we have replaced men with women to the limited extent which the nature of field work makes proper; we have lengthened hours of work in the field, not only to the maximum of 48 adopted in most understaffed industries, but in most instances to 50, and in some, to 60 hours per week. We have attempted, within the limits imposed by the War Labor Board rulings, to raise the earnings of our personnel to bring them at least within sight of what these same men could earn in other industries.

In times such as these when critical materials and manpower must be doled out with a thrifty eye to the many urgent war demands, we can hardly expect to have our every request granted. We can, and must, assemble the facts which govern our ability to support our part of the war effort and bring these facts home to those who control the over-all effort. If, having before them these facts accurately assembled and realistically interpreted, the War Manpower Commission and the War Production Board decide that a proportion of our facilities must be diverted and exploration curtailed, then, and only then, should we feel free to follow our impulse to get into work more spectacularly contributing to the war effort. The job assigned to us is one which nobody else can do, and I believe we should take every possible step to keep our facilities for executing this job unimpaired; we should not hesitate to make the strongest possible representation to our fellow workers in the industry and also to draft boards and other agencies in an endeavor to hold exploration staffs intact; far from being unpatriotic, I believe this is the most realistic contribution which we, as individuals or as professional societies, can make to the war effort.

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RESERVES IN ACTION[1]

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Last November, in an address at Chicago, I suggested that, under conditions of total warfare, a parallelism existed between the conditions on the military front and those on the industrial front. A military commander holds in reserve some portion of his forces "either to support hard-pressed units or to act as a striking force at a well-chosen moment." Similarly, an industry geared to war production should have, in addition to working stocks and materials being processed, adequate reserves of raw materials which can be drawn upon when needed to meet extraordinary demands. It is a primary responsibility of each such industry to plan its operations to that end.

With respect to this responsibility the petroleum industry occupies a peculiar and almost unique position. Its reserves of raw materials are almost entirely in underground storage, invisible, intangible, and not susceptible to the application of normal methods of inventory. Stocks above ground represent less than 20 per cent of the annual production and must be replenished five or six times a year from underground sources. The industry became conscious about 10 years ago of the need for having reliable information concerning the volume of oil carried in underground storage, and the American Petroleum Institute, with commendable wisdom, authorized an annual inventory of these underground stocks. The annual reports of these appraisals gave the industry for the first time a continuing basis for the study of its raw-material supply and an indication of the effect of new discoveries on the reserve position.

The information concerning reserves thus made available has exerted an important influence on policies, not only on those of various units of the industry but on those of various states and of the nation. Many companies have considered it to be the course of wisdom to discover and develop underground reserves which were large in comparison with their annual production requirements. Some states, heedless of the wisdom of conservation, placed no restriction on the production of newly discovered oil fields and followed the policy of "getting theirs while the getting was good." Those states and the war program as a whole are feeling today the results of these spendthrift policies. Other states, through the enactment of proration laws which prevented rapid and wasteful depletion, not only built up their underground reserves to higher levels but also greatly increased their capacity to produce regularly and efficiently immense volumes of oil.

In 1940 the industry could proudly say, in the words of one of its spokesmen: "Today those states which have practiced sound conservation principles have

[1] Read before the Association at Fort Worth, April 8, 1943. Manuscript received, April 8, 1943.

[2] Director of Reserves, Petroleum Administration for War.

built up tremendous underground reserves, available at a moment's notice for practically any emergency—and this without putting an extra load on the steel industry or the labor to drill thousands of new wells."

At that time, 1940, the petroleum industry had a backlog of oil stored in underground reservoirs of more than 18 billion barrels, and the presence and magnitude of this reserve were established on a sound engineering basis. It was the general opinion of the leaders of the industry that, with reserves of this size, it was in the best position of any basic industry to meet the demands of a war program, and that no other important industry had so few bottlenecks.

It is understandable that, as a result of such assurances, many should have concluded that the industry would have little need for expansion of facilities when we entered the war; some reasoned that there would be such a sharp decline in civilian requirements as a result of imposed war economies, that there would be a substantial reduction in over-all demand as compared with peace-time requirements. It then followed, according to this reasoning, that there would be little, if any, need for further oil-field development and that exploration would essentially cease for the duration.

A more far-sighted group, and I fear these were in the minority, looked ahead to military operations that would create unprecedented demands for almost every petroleum product, and foresaw that the need for such products in manufacturing and other industries would be greatly increased. They reasoned that the industry could not, therefore, relax its efforts toward making new discoveries and should endeavor to retain in its employ the manpower needed for the continuance of prospecting.

It is doubtful if anyone, two or three years ago, had the prescience to picture with accuracy our present situation. I am by no means sure that even now its full import has struck home to all those who control our destinies in the realm of oil.

What are the salient features of the present position?

1. Proved oil reserves stand at the highest level in the history of the American oil industry. They represent an immense supply of petroleum, for the most part developed, which is available for the use of industry and for the prosecution of the war. No other nation approaches our sufficiency in this respect.

2. Total proved reserves are indicated to have increased annually each year of the past 4 years but the annual increment has decreased in size. The increment for 1942 was only about half of that for 1937.

3. There is every indication that increases in proved reserves reported for several years past have come, to an increasing extent, from the extension of fields previously found and from the reappraisal of the reserves of previously known fields.

4. Estimates of the ultimate recoveries of the new fields discovered during the several years just passed show a falling-off, not only in the total amount of new reserves discovered but also in the size of the individual fields. The total reserves

of the new fields discovered in the last three or four years do not amount to as much as the oil produced in each of those years. The rate of production has thus exceeded the rate of discovery.

5. During recent years newly discovered fields have been more rapidly developed than formerly and have consequently reached peak production within a shorter time after discovery. What may be the extreme case is illustrated by the fact that 40 principal Illinois fields, discovered since 1937, reached their peak production, on the average, in 15 months after discovery.

6. Measurements of productive capacity, by various methods, have shown that wells in many areas, and especially in limestone fields, were individually capable of production at high rates. Such rates were far in excess of those at which the field could be produced without waste of reservoir energy and loss of ultimate recovery. Such figures created the belief that some states had very large productive capacities and could very greatly increase their oil output. The extreme case is that of one state whose proved reserve was less than one hundred times its total productivity, expressed in barrels per day.

7. The operation of fields of high productive capacity at excessive rates results in loss of ability to sustain the production and, once the peak of production is passed, in rapid decline. It is becoming all too apparent that, in many fields of varying characteristics, the rate of production must be reduced to prolong the lives of the fields and sustain productive capacity.

8. Over the last 5 years there has been a sharp decline in the average initial production of oil wells as reported by the producers. From an average of about 1,100 barrels per well in 1937 the average has declined to about 260 barrels per well in 1942. Furthermore, the total initial production of all wells completed in 1942 was only 12 per cent of that for 1937. These figures indicate a severe loss in new flush production during the period.

9. Most of the current oil production of the United States has been obtained from a relatively small number of wells. At present about 85 per cent of the oil comes from 27 per cent of the wells. The rest comes from wells whose production can not be materially increased. With current completions of new wells capable of large production falling off, we face either a decline in production or the necessity for a program of greatly accelerated development.

10. The decrease in the average size of newly discovered fields has, in turn, limited the opportunities for maintaining flush production. We can scarcely expect to offset the normal decline in productive capacity of old fields without a much larger measure of success than has flowed from the work of oil finding during the three or four years just past.

11. Although the number and footage of exploratory wells drilled last year was, with the exception of 1941, the largest in our history, the amount of the reserves discovered per well drilled was lower than at any time in many years. The number of wildcat wells being currently drilled is slightly higher than last year. While there is, of course, no direct relationship between the num-

ber of wildcat wells drilled and the amount of oil discovered, it would seem that the effort being currently exerted by the industry to discover new fields does not rise above the normal level.

12. Exploratory work, expressed in terms of geophysical crews in operation, has been at a higher average level over the past 12 months than at any time in history. It is a fair inference, I think, that it takes more work of this character now than formerly to find a promising prospect. The results of this increased effort of the industry to find new prospects will not become apparent for a considerable period, because of the time required for land work of various kinds.

We are facing the prospect of fighting a long and destructive war. The conflict will, we trust, be fought overseas and not on this continent. This greatly increases the material burdens of the conflict, for the supplies must be transported over long and dangerous sea lanes. Petroleum products form the largest part of the supplies to be shipped abroad and the losses in transit are heavy. If the summary of our oil position which I have just attempted approaches the truth, then this industry is challenged as never before to find, develop, and produce more oil.

This job of oil finding takes about 25,000 people. Approximately 10,000, as nearly as we know, are engaged in the application of geology and geophysics—about 5,500 in geology and 4,500 in geophysics, including not only technical people but their staffs. No definite figures are available as to the number of persons engaged in leasing and land work. Our guess, which may be low, is about 1,500. Wildcat drilling requires the services of about 12,000 men on a full-time basis. The work of all these persons engaged in many occupations, most of them highly skilled, is essential to the industry if the present program of exploration is to be carried forward. If, in spite of present exertions, the program is inadequate then more workers must be found and trained.

You ask how this may be accomplished. One of our tough field generals in the Far East recently set the pattern. He said, "The difficult we do at once; the impossible takes a little longer." It is in that spirit that this problem must be met and conquered. The first battle is one of psychology. A year ago many of our geologists and geophysicists felt that it was their duty to serve in the armed forces. Many of them, expert technicians, were capable of rendering highly important services in the design, construction, and operation of military and naval equipment and many of them were reserve officers. Their employers took the position that they would not take the responsibility of asking any man to stay out of uniform. As a result probably 20 per cent, perhaps more, of the staffs of exploration departments have gone into work of various kinds directly connected with the prosecution of the war. They are to be honored for their decision and their services are undoubtedly contributing in countless ways to the success of the fighting forces.

Now these depleted staffs bear the responsibility of doing all that those who have gone would have done, and more. But a point has now been reached where further reductions in numbers and quality will seriously impair their effective-

ness. Mr. McNutt, chairman of the War Manpower Commission, and Mr. Ickes, Petroleum Administrator for War, recently gave us our orders: "Oil and natural gas are vital to this war and it does not help to win the war for men who have long been trained and skilled in this industry to leave their present jobs." You may, therefore, as experienced technicians, have no hesitation in remaining at your post of duty confident that you are performing as essential, if not as dangerous, a task as the man in uniform.

Those of you who have the supervision and management of technical staffs must, in the face of the increasing demands of the services for recruits, take the responsibility of holding those staffs together. You must school yourselves in the methods for presenting to the representatives of the Selective Service System the essential character of your work and of the services of your employees. Most of your technical employees can only render effective service after years of training and more years of special experience. In most cases it is now impossible to train anyone to take their places. Many of you are seeking, without success, to employ others with similar qualifications. Surely, if you can not find others, you need no clearer proof that those now employed are irreplaceable.

Some draft boards are under great pressure to fill their quotas. The burden of proof rests on you to place before them convincing evidence of the essential nature of the work and of the impossibility of replacement. You must be prepared for their refusal of deferment even in the face of all your efforts. If you are right, appeal to the State board and then, if necessary, to the head of the Selective Service organization.

The Petroleum Administrator for War, under an Executive Order to "establish basic policies and formulate plans and programs to assure for the prosecution of the war the conservation and most efficient development and utilization of petroleum," is vitally concerned that essential manpower shall remain available to the industry. It is his policy to assist, in all proper ways, the maintenance of essential staffs. There is no function of the industry that causes greater concern than the development of new oil supplies. You may be assured, therefore, of our desire to help not only in general ways but in specific cases. To this end the following plans are being put into execution.

1. Occupations in the exploration branch of the industry are being redefined so as to indicate more precisely their functions and the need for such services.

2. Detailed evidence will be presented to the War Manpower Commission about the need for technical personnel, supporting a request that appropriate administrative units be set up to review individual cases on appeal.

3. A program of information and education is under way to assist employers of technical and skilled personnel in keeping them in essential jobs and to aid them in the solution of their deferment problems.

4. Detailed information concerning personnel in the exploration branch of the industry is urgently needed to support our representations to the War Manpower

Commission. General statements carry but little weight. We have asked the national service committee of this Association to aid us in obtaining this information and I trust that you will answer their inquiries as promptly and fully as you can.

In the struggle in which we are engaged the advantage in manpower now lies with our adversaries. To defeat them we must, man-for-man, be more resourceful, more efficient, more productive. Our capacity to produce is being tested as never before. It is none too soon to throw into the conflict all our knowledge of technique, all our administrative genius, all our capacity for coöperative effort. The reserves are being called into action.

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SOME FACTORS INFLUENCING THE DECLINING RATE OF CRUDE-OIL DISCOVERIES—THE GEOLOGIST'S RESPONSIBILITIES IN THE PRESENT SITUATION[1]

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ABSTRACT

The feeling that the exploration for new reserves should be accelerated is shared generally by most well informed oil men to-day. The subject of the decline in crude-oil discoveries is of particular importance to the geologist, who represents the backbone of the finding branch of the American petroleum industry. Upon his shoulders rests a major portion of the responsibility of maintaining ample crude-oil reserves with which to supply the necessary war requirements and essential civilian needs. The importance of the independent producer and the oil promoter in the finding effort of the industry can not be over-emphasized and everything possible should be done to encourage their continued operation and success.

Viewed over a substantial period of time, it appears that the declining discovery rate has been influenced more by other factors than by material shortage, manpower shortage, and crude price. In the immediate present, however, it is obvious that each of these three factors is seriously influencing the rate of discovery. The removal of these factors as retarding influences is perhaps the problem of others than the geologist, and it is hoped that to the extent necessary they will be corrected.

The relationship between the discovery rate in the Mid-Continent-Rocky Mountain-Gulf Coast region and the effect of the opening of new geological or prospective provinces within this area demonstrates the importance that new prospecting territories have played in maintaining the discovery rate. A study of the relationship between discovery rate and exploration methods indicates the importance which each new finding tool has played in maintaining finding rates. The influence of these two factors on the discovery rate within the area under discussion over the past 3–7 years has been profound and doubtless has been of major consequence in the declining rate of discovery in the entire United States.

Geologists and geophysicists should recognize their responsibility of extending the search for oil into new provinces which heretofore have received little, if any, attention. They should also accept the responsibility of providing new finding tools and of improving present exploratory methods.

To be invited to address a meeting of the American Association of Petroleum Geologists is an honor which any person will cherish for a long time. I am conscious of the weight of responsibility placed upon a speaker before such a group of oil-finding scientists. I want to thank you for honoring me with an invitation to address you to-day on the subject of "Some Factors Influencing the Declining Rate of Crude-Oil Discoveries—the Geologist's Responsibilities in the Present Situation."

The decline in crude-oil discoveries has been the topic of discussion by the producing branch of the oil industry for the past several months. The general decline in discoveries which has obtained from 1935 through 1942, is viewed as a hazard to this Nation's supply of crude oil and products. This subject is of prime importance to the geologists who represent the finding branch of the American petroleum industry. Upon our shoulders rests the responsibility of keeping the American nation supplied with ample crude-oil reserves to meet the necessary war requirements and essential civilian needs.

[1] Read before the Association at Forth Worth, April 8, 1943. Manuscript received, March 26, 1943.

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Recent estimates released by the PAW of crude-oil production required to meet the war needs and to supply essential civilian uses for the year 1943 are slightly less than 4 million barrels daily, with a peak production of perhaps 4,200,000 to 4,600,000 barrels daily during the last quarter of 1943. With the anticipated production decline in the older producing areas, the present shut-in capacity to produce in some of the newer areas will be taxed to meet the required production without physical waste.

I believe the feeling is shared generally by those informed on the oil industry that exploration for new reserves should be accelerated. The volume of oil discovered has declined over the past several years, whereas production has continued to increase. Without debating the question of whether or not discoveries should be increased, let us examine the record and attempt to determine why discoveries are declining, and endeavor to find a solution to reverse this trend. The discussion in this paper is based on data obtained largely from the Mid-Continent-Rocky Mountain-Gulf Coast region. The conclusions reached are probably generally applicable throughout the entire United States, inasmuch as the Mid-Continent-Rocky Mountain-Gulf Coast region produces approximately 80 per cent of the Nation's crude oil production.

In the upper left-hand corner of Chart I are shown the volume of discoveries of crude-oil reserves, by years (1900–1942, inclusive) in the Mid-Continent-Rocky Mountain-Gulf Coast region of the United States, which comprises PAW Production Districts 2, 3, and 4. Revisions in estimates of discoveries have been credited or charged as the case may be to the year in which the discovery was made. This chart is not new, but is presented to support the statement made earlier that discoveries have declined over the past several years. Discoveries were approximately the same in 1942 (375 million barrels) as in 1931–33, the "depression" years. This figure compares with discoveries of 655 million barrels in 1941 and 1,185 million barrels in 1940. The discovery of approximately 6 billion barrels of oil in 1930, the year of the discovery of the East Texas field, stands out strikingly and needs no comment. It is the decline in later years that interests us most at the moment, and to which we will devote most of our discussion.

In the upper right-hand corner of Chart I, production is plotted by years from 1900 to 1942, showing a rather constant increase in production to a peak in 1941 of 1,139 million barrels. The trend in production during recent years is inverse to that of discoveries, giving rise to the concern that is felt to-day by the industry that we may fail to meet without wasteful production practices our future demand for crude oil. In the lower left-hand corner of Chart I, you will see the average size of discoveries by years from 1900 to 1942. The peaks in the years 1901, 1905–6, 1908–9, 1912, and 1930 stand out strikingly, as do, also the scarcity of peaks in later years and the decline in average size of discoveries since 1930.

In contrast to the volumetric decline in discoveries during the past 3 to 7 years, and the decline in the average size of discoveries for the past 10 or 12 years, is the

total number of discoveries shown in the graph in the lower right-hand corner of Chart I. With the exception of the years 1931–33, there has been a gradual increase in the number of discoveries from 1900 to 1942, with the peak number of 275 discoveries being attained in 1941. Despite this increase in the number of discoveries, graphs on the left on Chart I indicate that the total volume of oil discovered annually has declined. This raises the doubt that our prospecting ter-

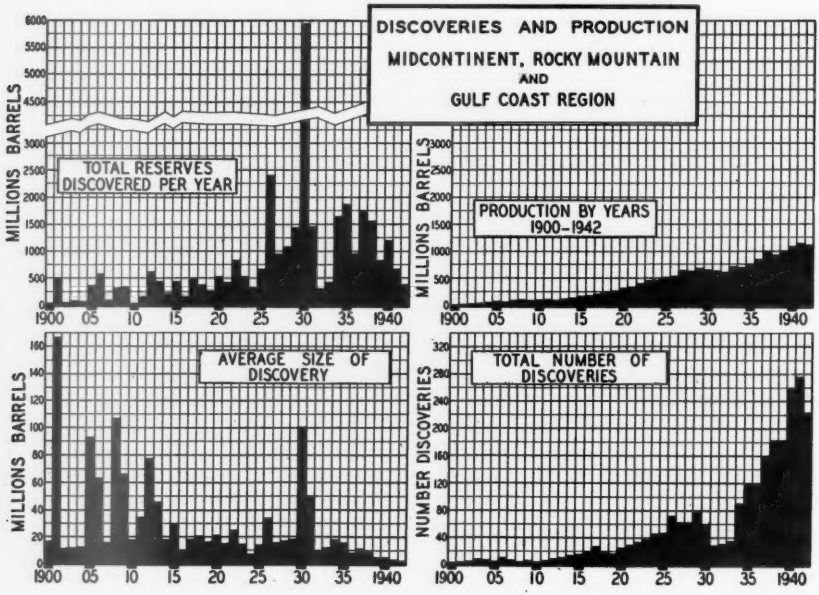
DISCOVERIES AND PRODUCTION
MIDCONTINENT, ROCKY MOUNTAIN AND GULF COAST REGION
TOTAL RESERVES DISCOVERED PER YEAR
MILLIONS BARRELS
PRODUCTION BY YEARS 1900–1942
AVERAGE SIZE OF DISCOVERY
TOTAL NUMBER OF DISCOVERIES
NUMBER DISCOVERIES
1900 05 10 15 20 25 30 35 1940

CHART I

ritory still holds hidden fields of large magnitude compared with East Texas, Oklahoma City, Yates, Conroe, Salem, Hobbs, and other fields.

The decline in total completions for this area from 23,148 wells in 1941 to 12,929 wells in 1942 (44 per cent) is striking. This decline is probably the direct result of federal spacing regulations and the shortage of materials—the shortage of materials creating the necessity for federal spacing regulations. The decline in dry holes drilled from 6,345 in 1941 to 4,967 in 1942, and the decline in wildcat completions from 3,255 in 1941 to 2,956 in 1942, may also be attributed at least partially to the shortage of materials.

It is obvious, at least during 1942, that the shortage of materials influenced crude-oil discoveries. With a continuing shortage of necessary materials and equipment, the rate of discovery may decline further. The search for new prospects and also the drilling of additional wildcat wells will be influenced by the

material situation. This problem is one which the industry must solve, and is receiving a great deal of attention. Since the matter is in capable hands, it is hoped that sufficient materials and equipment will be available during 1943 for the drilling of the necessary number of wildcats and to permit the desired amount of other exploratory work.

The shortage of manpower in the search for new discoveries is becoming acute. A number of manpower surveys are in the process of being compiled. The Lovejoy committee on manpower, in a preliminary report to the Petroleum Industry War Committee, states that the average loss of personnel by the petroleum industry to the armed forces runs approximately 15 per cent with the experience of individual companies varying from 5 to 35 per cent. This committee says that "the chief complaint running through the replies (to their questionnaires) shows a great difficulty in maintaining adequate technical men. This seems to be general, and is spread through all branches of the industry."

The technical staffs, the leasing staffs, and other members of the finding staffs of the operators, both small and large, have been severely depleted. Geologists and geophysicists, as well as others connected with the finding branch of the producing industry, have answered the call to the colors unhesitatingly. Of the total membership of the American Association of Petroleum Geologists, 14 per cent are either in the armed forces or in government-civilian service and hence are not available for exploratory work during 1943. Final figures on the loss of geophysical personnel have not been completed by the Society of Exploration Geophysicists. Preliminary figures indicate that 30 per cent of the geophysical personnel employed at the time of the Pearl Harbor attack have now gone into the services. Drilling crews for wildcat drilling purposes are increasingly harder to obtain and an acute shortage in drilling personnel threatens. Other members of the finding branch of the producing industry are occupied in work either directly or indirectly connected with the war, and hence are not fully available for exploratory work. There has also been a severe loss of other personnel engaged in the general effort of discovering new reserves.

Perhaps in the immediate present the importance of the manpower problem overhadows that of the material problem. *In order to find the oil which may be necessary in the future, there should be an immediate acceleration in the amount of geological and geophysical effort and the men required for this acceleration should be made available.*

No discussion of the principal factors influencing discovery rates would be complete without examining the effect or influence of price. Chart II shows by 3-year running averages the relationship between average crude-oil price, dry holes drilled, and discoveries from the entire United States for the period from 1900 to 1942. This chart shows a generally direct relationship between the average crude price, dry holes drilled (a measure of finding effort), and discoveries, but in recent years, with which we are principally concerned, this direct relationship fails to maintain itself.

The search for new reserves as measured by the dry holes drilled, has been generally upward from 1933 through 1941, with a decline in dry holes completed of 7,128 in 1941 to 5,500 (23 per cent) in 1942. From the year 1934 through 1942, the price of crude oil has remained fairly constant, fluctuating from a low of $0.96 per barrel in 1935 to $1.17 per barrel during 1942. Contrasted, however, to the somewhat uniform crude price from 1934 through 1942, and contrasted to

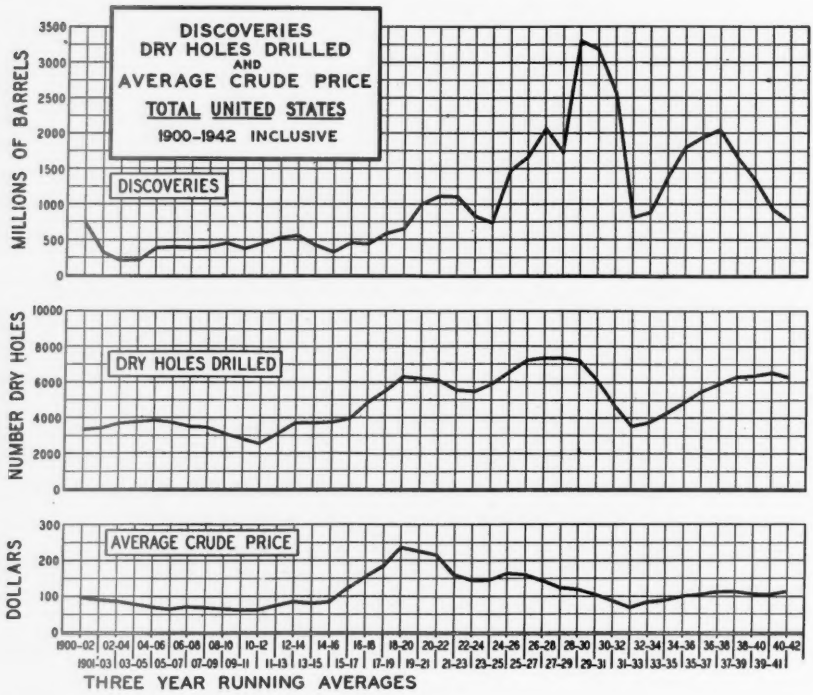

CHART II

the increased number of dry holes drilled as a measure of exploratory effort during the same period, is the general decline in reserves from 1937 through 1942. Dry holes drilled increased every year from 1933 through 1941, except for a slight decrease in the year 1938. Discoveries, however, declined from approximately 2,075 million barrels in 1937 to 420 million barrels in 1942, with declines occurring each year except in 1940.

This lack of correlation between discoveries, the number of dry holes drilled and the price of crude oil during the last few years requires further examination. The direct relationships between price, search, and discoveries prior to this period,

leads to the possible conclusion that other factors are operative to-day that were not present prior to this time. It appears from this chart that the major factor influencing this decline in discovery rate is not the material shortage, the manpower shortage, or the price of crude oil. It is probably worthwhile, then, to look further in search of other factors that are influencing the declining discovery rate for the past several years.

Chart I indicates that the total number of discoveries by years from 1900 to 1942, and particularly during the last few years, with the exception of the year 1942, have increased tremendously, as a matter of fact, increasing from approximately 30 discoveries in number in 1931 to 275 discoveries in 1941. During approximately the same period, with the exception of a few minor fluctuations, the average size of discoveries has declined from 18 million barrels in 1934 to less than 2 million barrels in 1942.

Upon examining the relationship between the discovery rate in the entire Mid-Continent-Rocky Mountain-Gulf Coast region and the effect of the opening of new geological or prospective provinces within this area, one is impressed with the importance of new prospecting territories in maintaining the discovery rate. A similar examination of the relationship between discovery rate and the exploration methods responsible for finding oil pools in this region indicates the importance of new finding tools in maintaining finding rates. A thorough study of the influence of these two factors on discovery rates during the past 40 years and a critical examination of the declining discovery rate during the past 3 to 7 years indicate that "the old field from which we have been raising our new crop of oil pools is becoming increasingly unproductive as a result of being constantly recultivated," and that the implements which we have used to find oil in these fields "are becoming increasingly dull and ineffective." Despite the improvement in the technique of finding oil over the past several years, the tools which we have used, although capable of finding an increasing number of fields, are less effective from the standpoint of the amount of oil found. Charts will be presented to illustrate these points.

Chart III shows the relationship between the discovery rate in the Mid-Continent-Rocky Mountain-Gulf Coast region and the opening of new geological producing areas within this region. As a new area is proved, exploration effort increases and the finding success rapidly builds up to a peak. Discoveries later run their course, after the new areas have been combed, and the discovery rate then descends. Chart III, at the top, shows discoveries in the Mid-Continent-Rocky Mountain-Gulf Coast region by years from 1900 to 1942. Beneath this is shown discoveries by years in certain geological producing areas for the same period. Note the direct relationship or influence between peak years of discoveries by geological provinces and the discoveries for the region as a whole. Note the influence of Arkansas discoveries in 1922 on the total discoveries for the area under discussion. Also, note the influence of discoveries in the Panhandle of Texas, the Seminole area of Oklahoma, and the West Texas area in the years

1925, 1926, and 1927 on total discoveries for the Mid-Continent-Rocky Mountain-Gulf Coast region. Generally, it may be seen from Chart III that *without the opening of new prospecting territory, discovery rates could not have been maintained.* Since the area of active search in the Mid-Continent-Rocky Mountain-Gulf Coast region has not been expanded materially in recent years, the decline in the rate of discovery may be due to the exhaustion of our hunting

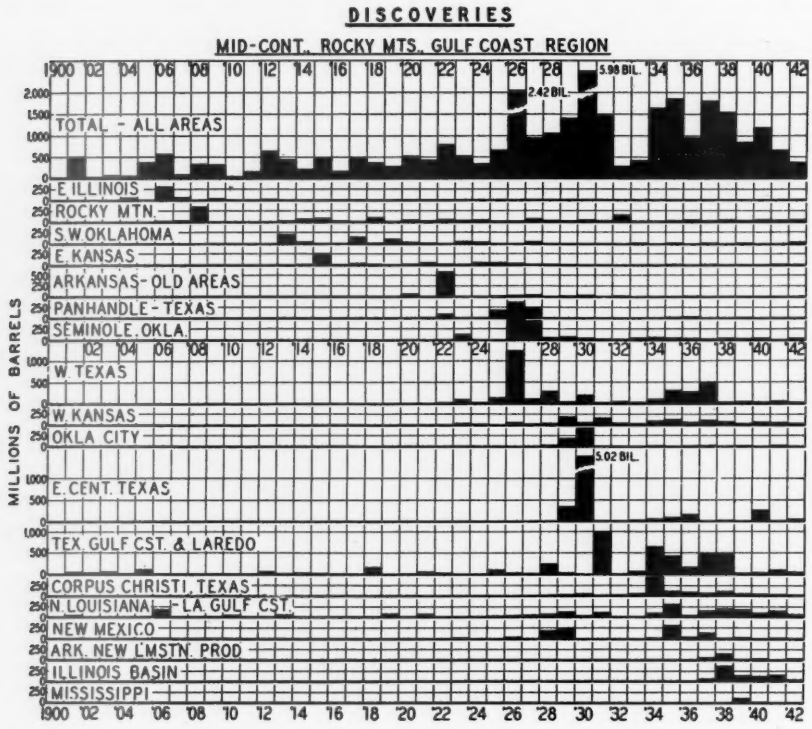

CHART III

grounds. In other words, "our finding field is becoming sterile from being constantly ploughed over."

The relationship between the volume of reserves discovered and the exploration method responsible for the discovery of oil pools in the Mid-Continent-Rocky Mountain-Gulf Coast region for the years 1900-1942, inclusive, is illustrated on Chart IV. This chart also shows the number of discoveries by exploration methods. On the right-hand side of this chart at the top is the same graph shown in the lower right-hand corner of Chart I, which brings out the increase in

the number of discoveries over the past 40 years. Also, on the right-hand side of this chart, is shown the total number of discoveries by each exploration method for the same period. Generally, this shows that each method of exploration is still effective insofar as its ability to find prospects is concerned. On the left-hand side of Chart IV is shown the amount of oil discovered annually from 1900 to 1942, inclusive. At the top of the chart there is again shown volume of discoveries, by years, for the period under discussion. Again, it should be pointed out that total discoveries have declined generally during the past 7 years.

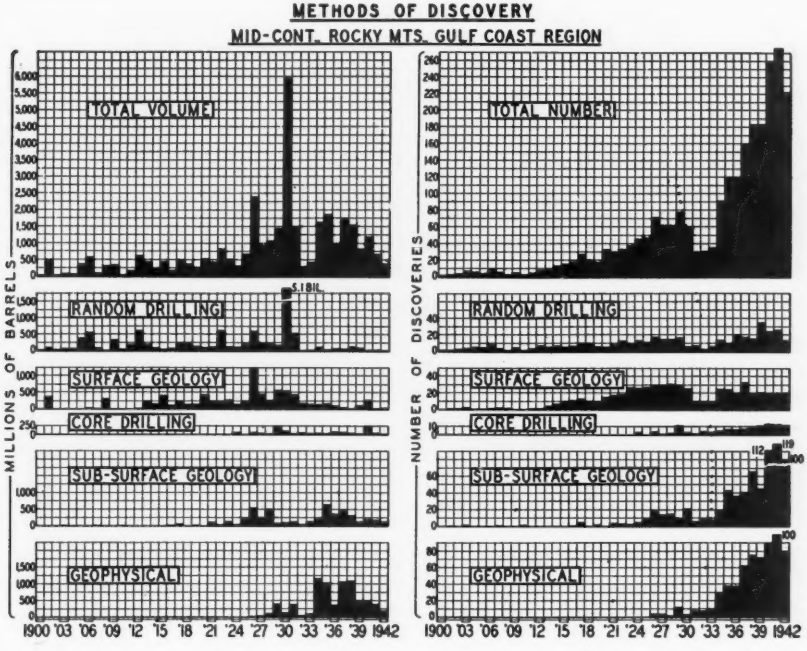

CHART IV

Beneath the graph at the top in the left-hand corner of Chart IV is shown the total oil discovered by years by the various finding methods. It is clear that there has been a rapid increase in the amount of oil discovered soon after the inception of each new method and that each method now is in a period of lessened effectiveness. It is also obvious that, *without the introduction of new finding methods, total discoveries would have been much smaller.*

Charts III and IV clearly illustrate that *our finding tools are less effective to-day than at any time heretofore* from the standpoint of the volume of oil being found, *and further illustrate the extreme need for developing new prospective territory in the*

Mid-Continent-Rocky Mountain-Gulf Coast region if the discovery rate is to be maintained. These two factors have profoundly influenced the discovery rate over the past 3 to 7 years, and, in my judgment, have been major causes of its decline.

Geologists and geophysicists should recognize the responsibility which they bear. We are the ones most capable of either improving our known exploration methods or of discovering new discovery methods. It has been obvious to most of us for some time that the relative effectiveness of our exploration tools is decreasing. Recognizing this fact, we should exert our influence on those who look to us to find oil to provide us with ample materials, manpower, and money to sharpen our present tools and to devise new ones. Likewise, it is up to us to extend our search for oil to new provinces. We know that we can not fertilize our old finding field and grow a new crop of oil pools. *We must move into new territory.* This will require carrying on exploratory activities in regions that heretofore have not received a great deal of our attention. It will be necessary to search for oil and drill wells in regions remote from our place of former activity, or from our operating headquarters. Our search should be more audacious and less cautious. Assuming that the same average size of discoveries during the last three years obtains for the next five years in the region being discussed, it will then be necessary to drill 5,100 wildcat wells annually, or 1.75 times the number of wildcats completed in 1942, to discover the oil we will produce annually.

The importance of the independent producer and the oil promoter in the finding effort of the industry can not be over-emphasized. There are many individual operators who do a large share of the wildcat drilling, and who often employ more geology in their operations than they themselves realize. The industry owes much of its success to these operators and everything possible should be done to encourage their continued operation and success.

We must accept the responsibility for improving our discovery rate. The improvement of exploratory methods and the discovery of new methods may bring increased costs. Likewise, exploring for oil in new regions, some of which do not appear attractive, may result in increased costs. These facts should be honestly and courageously faced. If we are to succeed in our efforts to maintain our discovery rate, the necessary funds with which to carry on the needed search must be provided.

The finding branch of the producing industry may be required to initiate and carry out an aggressive research program, designed to discover new finding tools or to improve our present methods. Such investigations might go further into the possibility of new instruments based on chemical, physical, or electrical phenomena. Enlarged regional stratigraphy and structural studies are desirable. Coöperative effort in this regard should yield valuable results.

As geologists, we may contend that the declining discovery rate is due to the material shortage, the manpower shortage, or to inadequate crude-oil prices. *If we face the facts, however, I believe we must admit that more potent factors in causing this decline are our failure for nearly a decade now to develop any radically*

new or improved finding techniques and our insistence on ploughing the same old fields. We need better implements and new fields to use them in.

The oil geologist's future is perhaps brighter to-day than ever before. Because of the need for exploration personnel, there will be a demand for his talents. The reward for qualified "explorationists" will be great. We are happiest when we have a job to do and are busy doing it. Upon our shoulders rests the responsibility for increasing our discovery rates. We may approach this task with confidence that the job can be done, and we will do it.

ACKNOWLEDGMENT

I wish to express my appreciation to members of The Carter Oil Company staff for their assistance in assembling the statistical data and in preparing the charts; also, to these people and other associates for their helpful suggestions and constructive comments.

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WARTIME CHANGES IN PETROLEUM INDUSTRY[1]

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INTRODUCTION

The petroleum industry did not feel the full effect of the war until 1942. Prior to that time, it had experienced an increase in demand following the outbreak of war in 1939, a loss of large European export markets in 1940, and the diversion of tankers to Great Britain in the summer of 1941. Adjustments to these developments were relatively easy, however, and the really difficult problems resulting from the war did not occur for the petroleum industry until this country became engaged in war. During 1942, the industry experienced major changes in its operations, the most outstanding of which were: (1) the necessity for increasing greatly the manufacture of critical petroleum war products, (2) the severe dislocation of transportation, and (3) a shortage of materials. The effect of the war on the industry can be visualized best by considering the changes in the major phases of the industry's activities.

TABLE I

WELL COMPLETIONS BY PETROLEUM INDUSTRY IN UNITED STATES

PAW District	*1939*	*1940*	*1941*	*1942*	*Annual Rate 1st ¼, 1943*
1 (East Coast)	3,950	5,800	6,300	3,525	2,550
2 (Mid-Continent)	10,300	11,000	12,000	7,125	5,750
3 (Gulf Coast)	11,600	11,750	12,250	6,350	4,500
4 (Rocky Mountains)	350	450	500	320	300
5 (Pacific Coast)	1,150	1,050	1,100	830	1,000
United States	27,350	30,050	32,150	18,150	14,100
Per cent change from previous year	+0.7	+9.9	+7.0	−43.6	−22.3

DRILLING

DECREASE IN WELL COMPLETIONS

The petroleum industry completed 18,150 wells in 1942, a decrease of 44 per cent from the previous year. Reduced drilling is primarily a result of the steel shortage and restrictions imposed by Conservation Order M-68 on well spacing, but is further aggravated by a lack of price adjustments. For the first quarter of 1943, the annual rate of completions is approximately 14,000 wells, or about 20 per cent under the low average last year, and the lowest level since 1914 except for the depression years of 1931 and 1933. District 3 (Texas, Louisiana, New Mexico, Arkansas, Mississippi, and Alabama) has suffered a greater decline in drilling than the average and is currently completing fewer wells than District

[1] Read before the Association at Forth Worth, April 8, 1943. Manuscript received, April 1, 1943.

[2] Humble Oil and Refining Company.

2 (the Mid-Continent area). The decline in drilling appears particulary sharp in relation to the record level of 33,000 completions in 1937 and 32,150 completions in 1941. The trend in total completions since 1939 is shown in Figure 1, where quarterly completions have been converted to an annual rate for comparison with previous years.

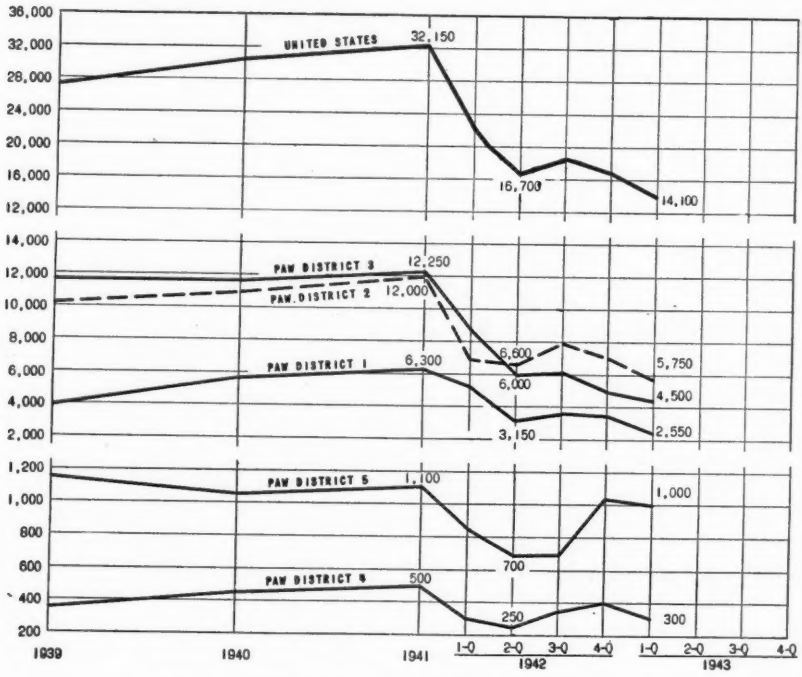


FIG. 1.—Annual rate of well completions in United States.

INCREASE IN PROPORTION OF DRY HOLES

Coincident with the decline in drilling, there has been a sharp increase in the ratio of dry holes because of the higher proportion of wildcats to total completions. The number of wildcats drilled in 1942 declined less than 10 per cent, although total well completions decreased 44 per cent. Consequently, wildcats constituted 17 per cent of the total completions in 1942, compared with 10 per cent in 1941. The ratio of dry holes to total completions increased from 22.4 per cent in 1941 to 31 per cent in 1942. It may be seen from Table II and Figure 2 that nearly one-third of the wells drilled in the United States recently have been dry holes, and that the ratio in Districts 2 and 3, which account for 95 per cent of United States wildcats, is more than 40 per cent dry holes.

RESERVES

In spite of the continued high level of exploratory efforts, both in the search for prospects and the drilling of wildcat wells, the amount of new oil discovered in recent years has been declining. According to the API Committee on reserves, new discoveries in 1942 were only 260,000,000 barrels, a decrease of 40 per cent

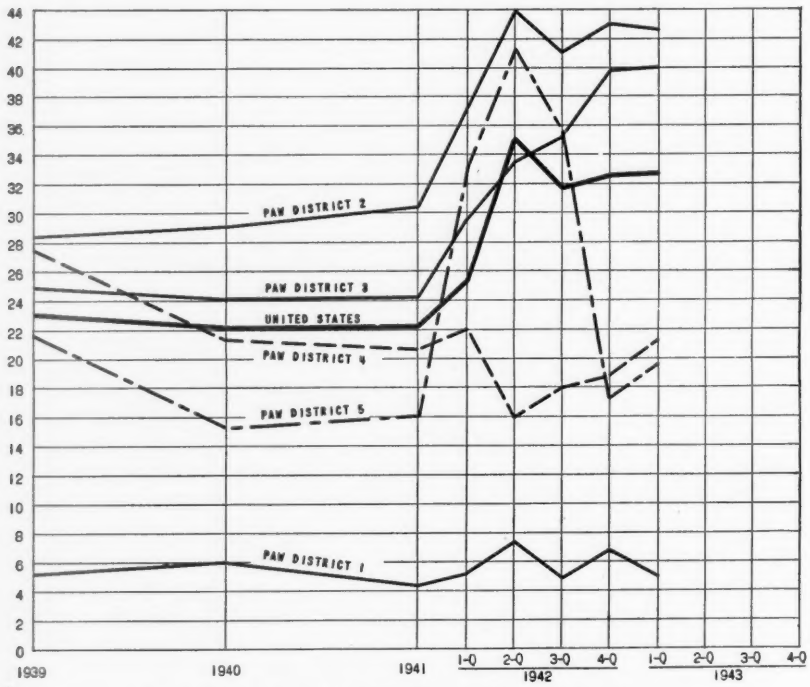


FIG. 2.—Per cent dry-hole completions to total wells completed.

from the previous year and of 70 per cent from the average for 1937–38. Revisions and extensions in 1942, however, were 1,619,000,000 barrels, or 80,000,000 barrels more than the previous year, but 900,000,000 barrels less than the average for

TABLE II

PER CENT DRY-HOLE COMPLETIONS IN UNITED STATES

PAW District	*1939*	*1940*	*1941*	*1942*	*1943 1st ½*
1	5.2	6.0	4.3	6.1	5.0
2	28.4	29.0	30.2	41.4	42.6
3	24.9	24.1	24.1	33.9	40.0
4	27.5	21.4	20.5	18.8	21.3
5	21.6	15.6	16.0	30.1	19.6
United States	23.2	22.1	22.4	31.0	32.6

1937–38. Net additions to reserves, after allowing for production, have decreased to 533,000,000 barrels per year in the past 3 years, compared with 1,800,000,000 barrels annually in the period 1937–39. Total reserves reported by the API increased from 13,000,000,000 barrels in 1937 to 20,000,000,000 barrels at the beginning of 1943, as indicated in Table III and in Figure 3. It should be kept in mind in studying these figures that the reserve estimates assigned to new discoveries are usually conservative and that upward revisions and extensions in subsequent years are frequently two or three times the amount originally estimated.

TABLE III

CHANGES IN ESTIMATED PROVED CRUDE-OIL RESERVES IN UNITED STATES

(Millions of barrels)

	Reserves—January 1				*Changes in U. S. Reserves*			
	Dists. 1 and 2	*Dist. 3*	*Dists. 4 and 5*	*U. S.*	*New Disc.*	*Rev. and Exts.*	*Prod.*	*Net Change*
1937	2,260	7,561	3,302	13,063	929	2,793	1,278	2,444
1938	2,350	9,700	3,457	15,507	810	2,244	1,213	1,841
1939	2,396	11,380	3,572	17,348	341	2,058	1,264	1,135
1940	2,576	11,955	3,952	18,483	286	1,607	1,352	541
1941	2,438	12,877	3,709	19,024	430	1,539	1,404	565
1942	2,496	13,356	3,737	19,589	260	1,619	1,385	494
1943	2,385	14,006	3,692	20,083				

It will be noted that the API estimates indicate a decline in reserves since 1940 outside of District 3, and that more than 90 per cent of the total increase in reserves in the past 6 years has occurred in District 3, principally in Texas and Louisiana. Texas' reserves alone increased 5,123,000,000 barrels since 1937 to 11,545,727,000 barrels now, which represents 82 per cent of District 3 and 57.5 per cent of the United States' reserves.

The participation of District 3 in total reserves has increased from 58 per cent in 1937 to nearly 70 per cent at the present time. Its participation in production, however, has remained at only about 50 per cent of the total for the United States, due to the fact that other areas have been depleting their reserves at a rapid rate. The figures for 1942 (Table IV) show that District 3 is producing only 5.1 per cent of its reserves per year, whereas District 2, for example, is producing about 17 per cent annually.

TABLE IV

PARTICIPATION IN CRUDE-OIL RESERVES AND PRODUCTION

PAW Districts	*Crude-Oil Reserves (Millions Bbls.)*		*Per Cent of Total Reserves*		*Per Cent Prod.*	*Per Cent Reserves Prod. Annually*
	1-1-42	*1-1-43*	*1-1-42*	*1-1-43*	*1942*	*1942*
1	231	255	1.2	1.3	2.0	11.5
2	2,266	2,130	11.6	10.6	27.6	16.9
3	13,356	14,006	68.2	69.7	49.5	5.1
4	414	496	2.1	2.5	3.0	10.1
5	3,323	3,196	16.9	15.9	17.9	7.5
U. S.	19,590	20,083	100.0	100.0	100.0	7.1

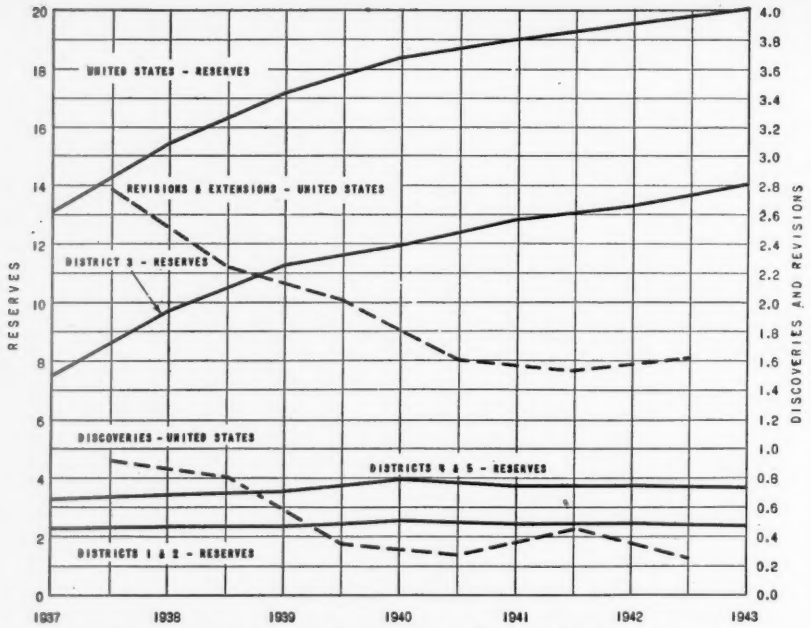


FIG. 3.—Proved crude-petroleum reserves and estimated new discoveries (billions of barrels).

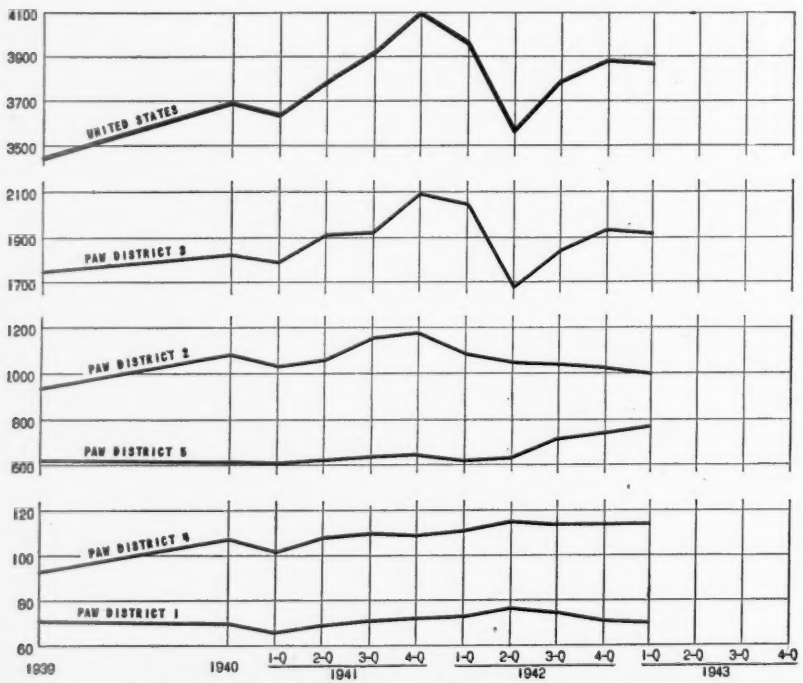


FIG. 4.—Crude-oil production (thousands of barrels per day).

PRODUCTION

CRUDE-OIL PRODUCTION DECREASE IN 1942

United States' crude production in 1942 averaged 3,796,000 barrels daily, which was only 46,000 barrels daily under the record production of 1941 and 100,000 barrels daily over production in 1940. The decrease in crude-oil production was offset by a gain in output of natural gasoline and condensate, so that 1942 production of all petroleum liquids was slightly above 1941. The trend in crude-oil production since 1939 by PAW districts is shown in Table V and in Figure 4.

TABLE V

CRUDE-OIL PRODUCTION IN UNITED STATES

(Thousands of barrels per day)

PAW			*1941*		*1942*					*1943*
Districts	*1939*	*1940*	*4th ¼*	*Year*	*1st ¼*	*2d ¼*	*3d ¼*	*4th ¼*	*Year*	*1st ¼*
1	71	70	72	71	73	76	74	71	73	70
2	944	1,088	1,187	1,107	1,086	1,048	1,039	1,021	1,049	995
3	1,743	1,820	2,094	1,925	2,066	1,681	1,843	1,931	1,880	1,925
4	93	107	110	108	111	116	115	115	114	115
5	615	612	644	631	627	638	713	742	680	775
U. S.	3,466	3,697	4,107	3,842	3,963	3,559	3,784	3,880	3,796	3,880

It will be noted that crude-oil production reached a record level of 4,107,000 barrels per day in the fourth quarter, 1941, at which time District 3 was producing 2,094,000 barrels daily. Except for a rapid decline in District 2, production continued at a high level in the first quarter of 1942, but this resulted in a large accumulation of stocks. The serious dislocation of transportation in the second quarter, 1942, forced a reduction in crude output to 3,559,000 barrels daily, followed by a recovery in the latter half of the year as transportation improved. In recent months, production has reached a relatively stable daily level of 3,880,000 barrels, which is about in balance with demand, but it is likely that a higher level will be required later this year, due to increased refinery runs to make additional war products.

There has been a marked difference in the trend of crude production in the various PAW districts. Daily production in District 5 has shown a rather steady increase from a level of 612,000 barrels in 1940 to about 775,000 barrels at the present time. District 2, which includes the important producing states of the Mid-Continent, increased rapidly in 1940 and 1941, due to the influence of Illinois' production, and declined steadily after the fourth qaurter, 1941. Production in this district is now 200,000 barrels per day less than the peak of 1,187,000 barrels daily in the fourth quarter, 1941, and is expected to continue declining. As the largest and marginal source of crude supply, District 3 naturally has accounted for the major adjustments in production. Production per day in this area advanced from 1,743,000 barrels in 1939 to 2,094,000 barrels in the fourth quarter, 1941, then declined very sharply to 1,681,000 barrels in the second quarter, 1942, due to the loss of tankers, and has since recovered to a

level of about 1,925,000 barrels. It may be noted from Figure 4 that the trend in United States' production follows closely the pattern of District 3.

INCREASE IN NATURAL-GASOLINE OUTPUT

The average daily production of natural gasoline and condensate has nearly doubled from the level of 141,000 barrels in 1939 to about 245,000 barrels currently, as a result of the discovery of large gas-condensate fields and completion and expanded production of cycling plants. The large proportion of this material which goes into the production of motor gasoline further complicates the industry's problem of reducing the yield of motor gasoline in line with the restricted market. District 3 accounts for 60 per cent of the production, as indicated in Table VI and Figure 5.

TABLE VI

NATURAL-GASOLINE AND CONDENSATE PRODUCTION IN UNITED STATES

(Thousands of barrels per day)

PAW Districts	*1939*	*1940*	*1941*		*1942*					*1943*
			4th ¼	*Year*	*1st ¼*	*2d ¼*	*3d ¼*	*4th ¼*	*Year*	*1st ¼*
1	5	5	7	6	6	6	6	9	7	9
2	33	32	37	34	47	45	45	49	45	50
3	58	71	107	91	138	121	131	135	133	140
4	6	6	7	7	3	3	3	3	3	3
5	39	38	38	38	41	40	42	43	41	43
U. S.	141	152	196	176	235	215	227	239	229	245

TRANSPORTATION

In no branch of the petroleum industry has the war forced more drastic adjustments than in the field of transportation. Under normal conditions, the petroleum industry was dependent on highly specialized transportation, including pipe lines, tankers, tank cars, barges, and tank trucks, for handling its raw materials and refined products. The major change caused by the war involved the loss and diversion of tankers. This has been offset by construction and rearrangement of pipe lines and the use of tank cars for long hauls to District 1, rather than for local distribution. The magnitude of the readjustment is indicated by the fact that tankers accounted for 95 per cent of the petroleum deliveries of 1,500,000 barrels per day into District 1 in the first quarter of 1941, but for less than 10 per cent of the deliveries of about 1,100,000 barrels daily in January, 1943.

TANKERS

The loss and diversion of tankers had its greatest effect upon movements from the Gulf Coast to the East Coast and on imports and exports. Daily tanker movements of crude and products to the East Coast, which amounted to about 1,200,000 barrels from the Gulf Coast and 225,000 barrels of imports in the first quarter of 1941, declined to a total of about 100,000 barrels daily in January, 1943. Figures on exports from the United States, which are handled almost en-

tirely by tanker, are no longer available. However, the effect of the war is evident from the fact that they declined from 518,000 barrels daily in 1939 to 255,000 barrels daily in the first half of 1941.

The first sharp effect of the war upon transportation was the diversion of approximately 80 tankers to British service in the summer of 1941. The reduction in the available tankers was offset to a large extent at that time by heavier load-

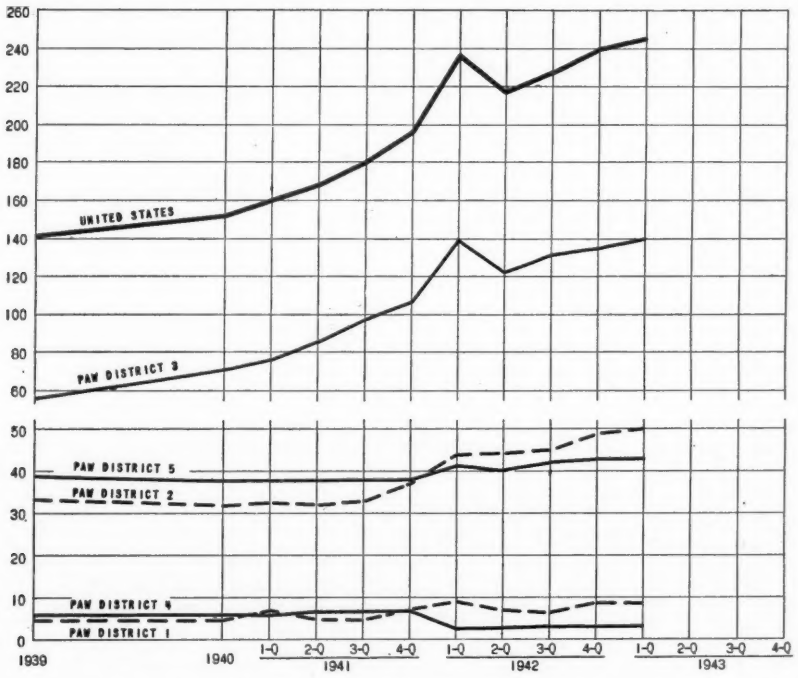


FIG. 5.—Natural-gasoline production (thousands of barrels per day).

ings, quicker turn-arounds, and increased operating speeds. In 1942, due to increasing tanker requirements for our military forces and to the submarine campaign along the Atlantic Seaboard, the volume of tanker deliveries to the East Coast from the Gulf Coast and South America declined very rapidly. There resulted quickly a major supply problem for District 1, which brought about gasoline rationing in that area long before it was introduced nation-wide as a measure for the conservation of rubber. It was recognized promptly that in spite of a large program of tanker construction, military requirements for tanker movement would be such that only limited tanker deliveries to the East Coast could be counted on. In 1942, 62 tankers were completed in the United States, an increase

of 120 per cent over the 1941 production, and the new ships were larger and faster than those of the peacetime fleet. The 1943 schedule of tanker construction is even greater, but because of increased military requirements, there may be no additional tankers available for the normal domestic movements. Therefore, plans which were made a year ago to meet the tanker shortage by increased use of overland facilities have proved basically sound.

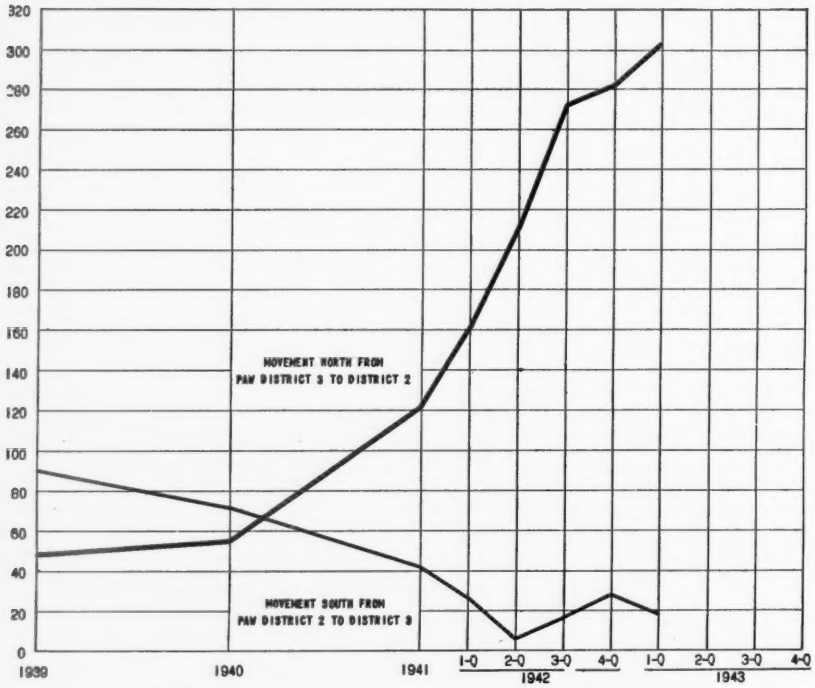


FIG. 6.—Movement of crude petroleum by pipe lines between PAW Districts 2 and 3 (thousands of barrels per day).

PIPE LINES

The capacity for delivering petroleum to the East Coast by pipe line prior to the war was very limited, because the cost of transportation by tanker was so much lower. Pipe-line deliveries into District 1 were only about 50,000 barrels daily in the early part of 1941. Two basic policies were pursued in order to increase pipe-line deliveries into District 1: (1) the rearrangement of existing pipe lines by reversals and expansions, and (2) the construction of new pipe lines.

The effect of a rearrangement of pipe lines is evident in increased pipe-line deliveries to District 1 and larger movements from District 3 to 2. District 1 is

currently receiving nearly 150,000 barrels daily by pipe line, or three times the normal peacetime amount. This has been accomplished by reversing some lines which previously moved from the East Coast into the interior and by expanding the capacity of others. In order to make as much crude as possible available at the closest point of tank-car shipment to District 1 and offset the declining production in District 2, there has also been a large increase in the movement of crude oil north into the Mid-Continent during the past year. For the first quarter of 1943 there will be a net movement north of 285,000 barrels daily by pipe line into District 2, whereas as late as 1940, there was a net movement south of 16,000 barrels daily from Oklahoma to Texas. This change in the flow of crude is reflected in Figure 6 and in Table VII, which exclude movements through the 24-inch line, because they are destined for District 1.

TABLE VII

PIPE-LINE MOVEMENTS BETWEEN DISTRICTS 2 AND 3
(Thousands of barrels per day)

				1942					1943
Movement	*1939*	*1940*	*1941*	*1st ¼*	*2d ¼*	*3d ¼*	*4th ¼*	*Year*	*1st ¼*
South	91	72	42	27	5	17	18	19	18
North	48	56	121	160	211	273	282	232	303
Net North	−43	−16	+79	+133	+206	+256	+254	+213	+285

The principal new pipe-line project to date has been the 24-inch War Emergency Line from East Texas, which is already completed and in partial operation to Illinois and should be completed to the East Coast some time during the summer of this year. This line has a capacity of 300,000 barrels per day, and will handle crude and heating oil. While it is operating to Illinois, its effect will be to shorten the tank-car haul and increase deliveries to the extent of about one-third of its capacity. When the line is completed to the East Coast, District 1 will receive the full benefit of 300,000 barrels daily. At that time, daily pipe-line deliveries into District 1 will be about 475,000 barrels. In addition, approval has been granted recently for the critical materials required to build a 20-inch product line from the Texas Gulf Coast to Illinois. This line will handle 235,000 barrels per day of gasoline and increase deliveries to District 1 about 110,000 barrels daily, due to shorter tank-car hauls. If approval is granted promptly on PAW's request to extend this line to the East Coast, the entire line may be in operation to District 1 by the end of this year.

INCREASE IN TANK-CAR DELIVERIES

Because of the difficulty of securing steel and equipment and the time required for new construction, pipe lines to date have played a subordinate rôle to tank cars in relieving the shortage in District 1. The industry and the railroads have done an outstanding job in placing 71,000 tank cars, representing two-thirds of all petroleum tank cars, in District 1 service. Tank-car deliveries to District 1 in normal times were negligible. They increased steadily during 1942, as tanker

TABLE VIII

TANK-CAR SHIPMENTS OF CRUDE PETROLEUM AND PRODUCTS TO PAW DISTRICT 1

(Thousands of barrels per day)

Week Ending	*Amount*	*Week Ending*	*Amount*	*Week Ending*	*Amount*	*Week Ending*	*Amount*
1- 3-42	64	4-25-42	565	8-15-42	831	12- 5-42	767
1-17-42	77	5- 9-42	652	8-29-42	823	12-19-42	744
1-31-42	165	5-23-42	707	9-12-42	838	1- 2-43	775
2-14-42	257	6- 6-42	667	9-26-42	836	1-16-43	818
2-28-42	324	6-20-42	732	10-10-42	766	1-30-43	796
3-14-42	439	7- 4-42	721	10-24-42	759	2-13-43	807
3-28-42	506	7-18-42	749	11- 7-42	769	2-27-43	798
4-11-42	586	8- 1-42	784	11-21-42	769		

deliveries became progressively smaller, as shown in Table VIII and Figure 7. Maximum tank-car deliveries of 830,000 barrels daily were realized in September, 1942, followed by a decline in the fourth quarter, due to winter weather and some withdrawal of tank cars for other service. In the fourth quarter, tank cars accounted for 70 per cent of the total petroleum shipments of 1,100,000 barrels per

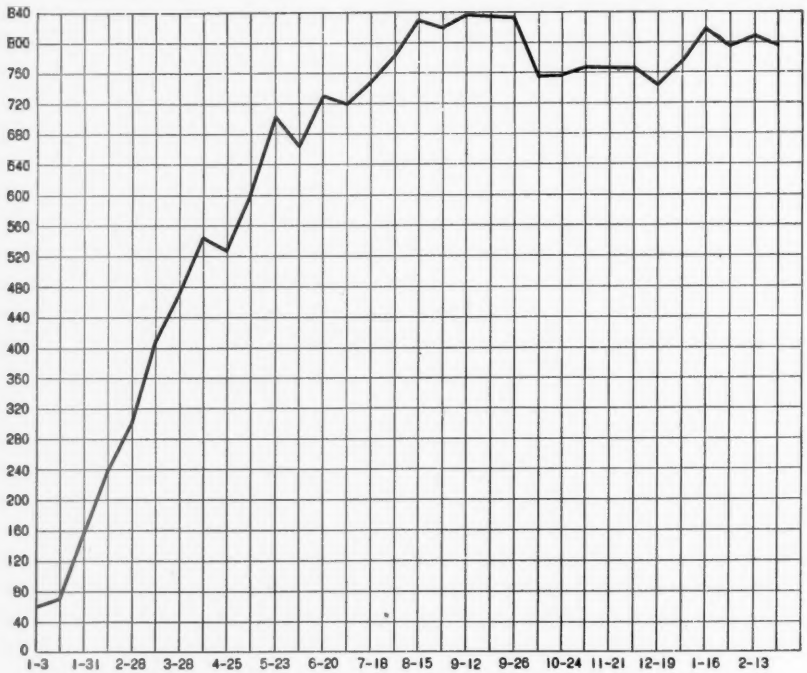


FIG. 7.—Tank-car shipments of crude petroleum and products to PAW District 1 (thousands of barrels per day).

day into District 1 and far overshadowed the tanker movements of 100,000 barrels daily, pipe-line deliveries of 135,000 barrels daily, and barge receipts of about 90,000 barrels daily.

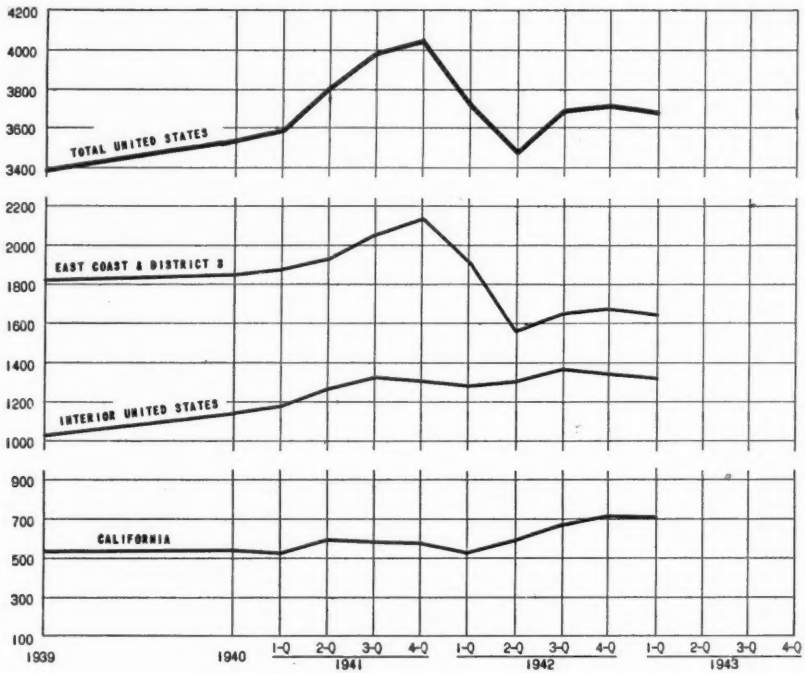


FIG. 8.—Refinery crude runs to stills (thousands of barrels per day).

REFINING

Operations of petroleum refineries have been complicated by the war in two major respects: (1) the increase in requirements for aviation gasoline, toluene, and other petroleum war products; and (2) the readjustment in product yields required by the decline in motor-gasoline demand, due to the rubber shortage and rationing. These tasks have been further complicated in the important Gulf-East Coast refinery area by reduced throughput as a result of inadequate transportation. A great deal of progress has already been made in dealing with these problems, but even further adjustments will be required in the future.

CRUDE RUNS TO STILLS

Daily refinery crude runs to stills in the United States increased steadily from 3,390,000 barrels in 1939 to a record level of 4,060,000 barrels in the fourth

quarter, 1941. Because of the transportation difficulties, a sharp reduction in runs occurred during the first half of 1942. By the second quarter, refinery runs had been reduced 573,000 barrels daily, or 14 per cent but all of the adjustment had come in the East Coast and District 3, where it amounted to a reduction of 27 per cent. Refinery runs in the interior of the United States (District 2, District 4, and the Appalachian area) have remained above the level in the fourth quarter of 1941, and runs in California have increased by more than 100,000 to 705,000 barrels per day in the first quarter, 1943. Runs in the East Coast and District 3 have improved slightly over the low level of the second quarter, 1942, but will still average in the first quarter of 1943 only 76.5 per cent of the fourth quarter, 1941, compared with a rate of more than 100 per cent in the Interior United States and 118 per cent in California. These trends are shown in Table IX and in Figure 8.

TABLE IX

REFINERY CRUDE RUNS TO STILLS IN UNITED STATES

(Thousands of barrels per day)

			1941		1942					1943
	1939	*1940*	*4th ¼*	*Year*	*1st ¼*	*2d ¼*	*3d ¼*	*4th ¼*	*Year*	*1st ¼*
California	544	549	593	584	527	608	674	712	631	705
East Coast and Dist. 3	1,822	1,842	2,150	2,007	1,917	1,568	1,651	1,674	1,700	1,645
Interior U. S.	1,025	1,145	1,315	1,270	1,282	1,309	1,363	1,333	1,323	1,320
U. S.	3,391	3,536	4,058	3,861	3,726	3,485	3,688	3,719	3,654	3,670

INCREASED REQUIREMENTS FOR WAR PRODUCTS

The principal military requirements on refineries have been for aviation gasoline and lubricants, toluene for explosives, fuel oils for the Navy, and components for synthetic rubber. Total production of aviation gasoline in 1941 was only 57,000 barrels daily. It has probably been expanded several fold by this time, in order to keep pace with the ever increasing aviation program. Aviation gasoline production requires special crudes and some special equipment. The yield of aviation gasoline varies widely between different crudes and processes, and it has been necessary to use increasing quantities of those crudes with a high aviation-gasoline yield in the Gulf Coast, which is by far the leading area in the production of critical petroleum products. Even those crudes best suited for aviation gasoline yield large quantities of non-war products, such as motor gasoline and distillates, for which adequate outlets must be found. As transportation improves, and later as additional quantities of synthetic rubber are made available for civilian use, it will probably be desirable to relax or remove current rationing restrictions in order that refineries may dispose of all the co-products inevitably manufactured when producing the required war products. It is of interest to note that the petroleum industry has been called upon to provide a large part of the raw materials in the synthetic-rubber program. Although the components for synthetic

rubber will represent a relatively small volume to the petroleum industry, the production of this material is of great significance in that it will influence directly the civilian demand for motor gasoline.

The war has produced a much larger demand for residual fuel oil, both for use in industrial plants and by the Navy. The manufacture of sufficient quantities

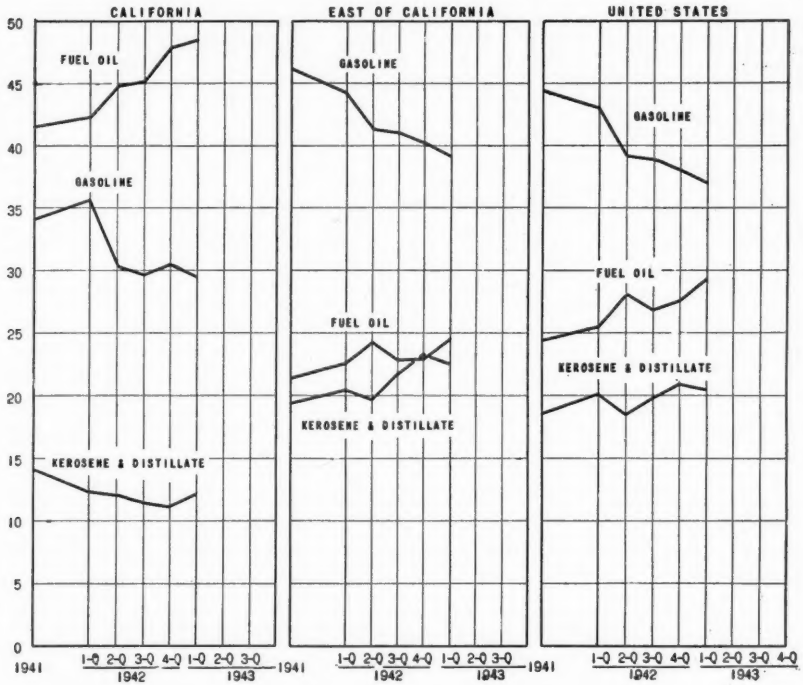


FIG. 9.—Per cent product yields on crude runs to stills.

of this product has required a sharp increase in yields at the expense principally of yields of gasoline, as the proportion of kerosene and distillate has remained relatively constant. These trends in yields are shown in Table X and in Figure 9.

PETROLEUM STOCKS

The shortage of transportation has had a significant effect upon total petroleum stocks and their distribution between areas. In the East Coast, available stocks have been reduced to less than 30 per cent of normal working levels, in spite of severe restrictions on consumption. By contrast, in District 3, and particularly in Texas, there developed a surplus of crude and products which could not be moved to markets. Stocks of crude located in Texas increased over 16,000,000

TABLE X

PER CENT PRODUCT YIELDS ON CRUDE RUNS TO STILLS IN UNITED STATES

	1941	1942				1943
		1st ¼	2d ¼	3d ¼	4th ¼	1st ¼
CALIFORNIA						
Gasoline	34.0	35.5	30.3	28.9	30.4	29.5
Kerosene and distillate	14.1	12.3	11.9	11.2	11.1	12.2
Fuel oil	41.5	42.2	44.9	44.3	47.9	48.5
EAST OF CALIFORNIA						
Gasoline	46.1	44.3	41.1	41.0	40.2	39.1
Kerosene and distillate	19.4	20.4	19.7	21.4	23.2	22.5
Fuel oil	21.4	22.5	24.4	23.0	22.8	24.6
UNITED STATES						
Gasoline	44.3	43.1	39.2	38.8	38.0	37.0
Kerosene and distillate	18.6	20.0	18.4	19.5	20.9	20.5
Fuel oil	24.4	25.3	28.0	26.9	27.6	29.3

barrels in 1942, or 44,000 barrels per day, which reflects the total accumulation in District 3. Product stocks in District 3 showed an increase, particularly distillate oils, although residual fuel oils declined. In the Mid-Continent there was a large draft on stocks of both crude and products. In spite of the large accumulation in District 3, stocks east of California were reduced 44,000,000 barrels. In California, stocks of products, principally residual fuel oil, were reduced substantially, and crude stocks declined slightly. For the United States, there was a net draft on stocks of all oils of 56,000,000 barrels, or 155,000 barrels per day. This reduced stocks of all oils to the lowest level since 1923. The changes in petroleum stocks since 1939 are shown in Table XI and in Figure 10.

TABLE XI

STOCKS OF CRUDE PETROLEUM AND PRODUCTS IN UNITED STATES

(Millions of barrels at end of period)

	1939	1940	1941	1942				1943
				1st ¼	2d ¼	3d ¼	4th ¼	1st ¼
California								
Crude	48.6	47.6	45.8	50.3	46.6	45.1	43.6	45.0
Products	103.5	97.7	91.7	86.1	81.3	81.6	82.0	81.0
All oils	152.1	145.3	137.5	136.4	127.9	126.7	125.6	126.0
East of California								
Crude	204.7	229.0	211.3	223.3	215.7	205.1	201.6	204.0
Products*	169.1	190.3	201.8	183.9	168.9	176.0	167.6	163.0
All oils*	373.8	419.3	413.1	407.2	384.6	381.1	369.2	367.0
United States								
Crude	253.3	276.6	257.1	273.6	262.3	250.2	245.2	249.0
Products*	272.6	288.0	293.5	270.0	250.2	257.6	249.6	244.0
All oils*	525.9	564.6	550.6	543.6	512.5	507.8	494.8	493.0

* Excluding kerosene stocks at bulk terminals

PETROLEUM PRICE TRENDS

The wartime changes in the petroleum industry would have been easier to make but for controlled crude and product prices. Maximum price ceilings handicapped early efforts to readjust transportation to the East Coast, efforts to secure changes in product yields, and other readjustments. For a considerable

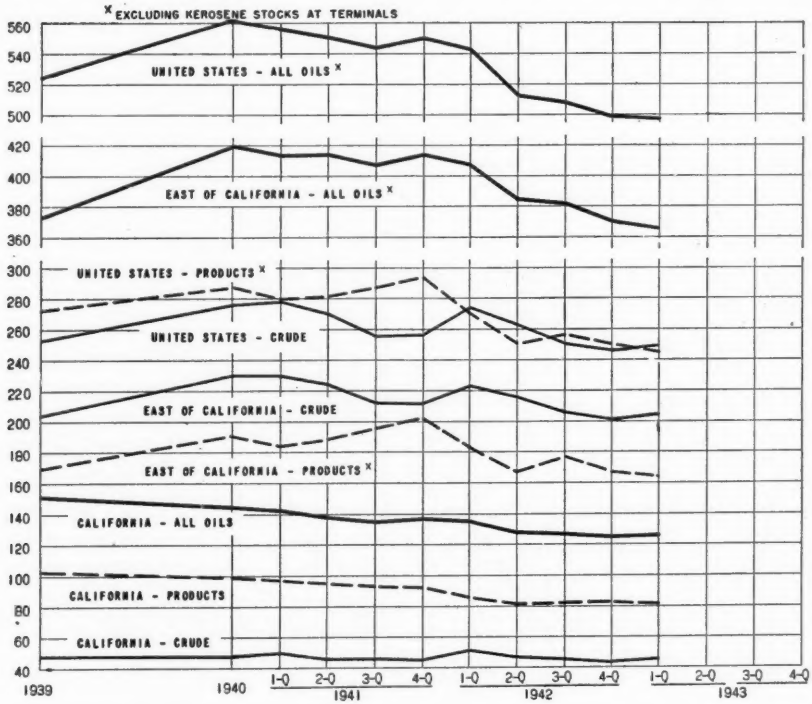


FIG. 10.—Stocks of crude petroleum and products (millions of barrels at end of period).

period of time after the transportation shortage developed, the petroleum industry had to absorb a tremendous extra transportation cost by substitute methods. Price adjustments granted lagged behind the rapidly increasing transportation costs, and it was not until August, 1942, that a satisfactory solution was achieved when the Reconstruction Finance Corporation assumed the abnormal costs.

COMPARISON OF PRICE TRENDS WITH ALL COMMODITIES

The advance in prices of crude petroleum and products since the outbreak of war in 1939 has been considerably less than for other commodities. According to the price index of the United States Bureau of Labor Statistics, the Petroleum

TABLE XII

INDEX OF PRICES (1926=100)

	All-Commodity Index	*Petroleum-Product Index*	*Crude-Price Index*	*Average Crude Price (Cents Per Bbl.)*
1929	95.3	71.3	67.6	1.27
1931	73.0	39.5	34.6	.65
1937	86.3	60.5	62.8	1.18
1939	77.1	52.1	54.2	1.02
1940	78.6	50.0	54.3	1.02
1941	87.3	57.0	60.6	1.14
1942	98.8	59.8	62.8	1.18
1943–1st ¼	102.0	61.0	62.8	1.18
Per cent change from 1939	32.3	17.1	15.8	15.8

index in the first quarter of 1943 will show an increase of only 17 per cent over 1939, compared with 32.3 per cent for all commodities. The crude-price index shows approximately the same gain as for petroleum products. It may be noted in Table XII and in Figure 11 that the index of all commodities is currently higher than in 1926 or 1929, while crude petroleum and products are substantially lower.

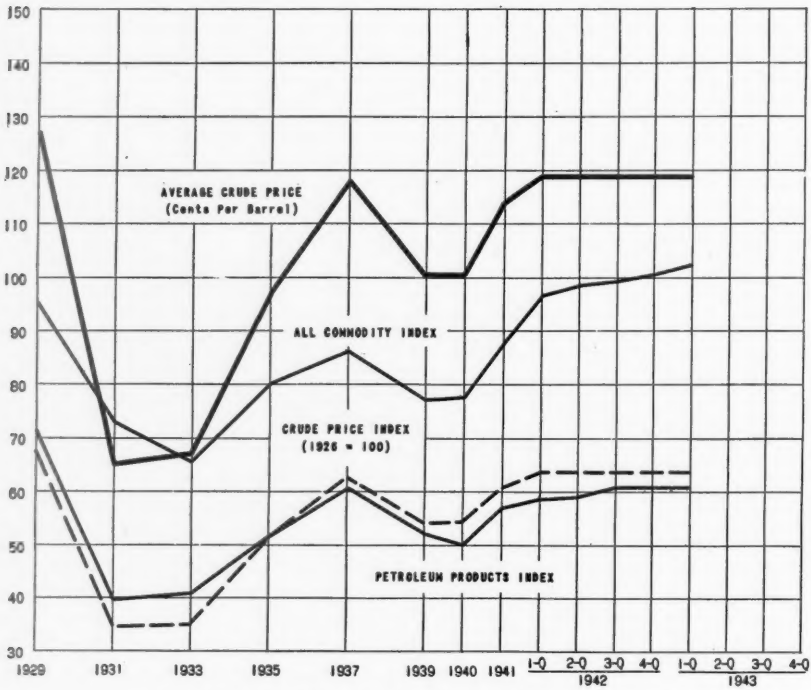


FIG. 11.—Index of wholesale prices (U. S. B. L. index: 1926=100).

PRODUCT PRICE CEILINGS

The necessary adjustments in refinery yields to meet an increase in residual fuel-oil demand and a decline in gasoline demand were delayed and hampered for a long time by the failure to adjust ceiling prices for products. In normal times, the increase in fuel-oil demand would have been reflected in higher prices and refineries would have found it economically advisable to adjust yields. Under price controls, however, there was a lag of nearly a year in securing the necessary adjustment. It was not until March, 1943, that the OPA authorized a general increase in the price ceiling for fuel oil throughout the country. In California, the advance was a flat increase of 25¢ per barrel, but in the area east of California, the change was made by establishing prices based on the gravity of fuel oil. This authorization of higher prices in proportion to the increase in gravity will encourage an increase in fuel-oil yields. An adjustment has also been authorized recently of ¼¢ per gallon in kerosene prices in the Gulf Coast, reflecting a shortage of this product.

The control of prices of petroleum products is a difficult matter which requires great care, if operations in the industry are not to be disturbed badly. The recent changes made in the price of fuel oil and kerosene are necessary to meet demand, but they tend to place these products out of line with the price for distillate oils. If this discrepancy should prove too great, the supplies of distillate may decline more than is desirable and still another adjustment will be required. In the absence of a normal competitive market, correct price relations are arrived at by a trial and error process, and numerous small changes made promptly may be required to establish the proper balance.

CRUDE-OIL PRICES

Present crude-oil prices, with a few exceptions such as the Pennsylvania-type oils and low-gravity crudes in California, are at the maximum of October, 1941, established by the Office of Price Administration as the ceiling level. These ceilings have been maintained in spite of many developments affecting the demand for crude and the cost of finding and producing oil. OPA officials have recently stated that a general advance in the price of crude is not justified, on the basis that the Tariff Commission study of costs indicates "that both the price of a barrel of oil and the margin of realization above cost of production are greater than in most recent years." The validity of this conclusion becomes highly questionable when consideration is given to four major limitations and omissions in the Tariff Commission report discussed in the following paragraphs.

1. The comparison of prices and costs with 1939 as a base period is unsatisfactory. The year 1939 was an abnormally poor one for the industry, with the lowest level of crude prices since the depression 10 years ago. Net earnings of oil companies in 1939 were 43 per cent lower than in 1937, whereas all industrial companies had earnings better than in 1937. The average price of crude oil of $1.11 per barrel in the first nine months of 1941 was higher than the level of $1.02 in 1939, but under the average of $1.13 in 1938 and $1.18 in 1937.

2. The Tariff Commission report gives no consideration whatever to a return on invested capital. This is in sharp contrast to the report by the Petroleum Administrative Board for 1931–34, when interest was taken into account at the rate of 6 per cent on invested capital. Taking the figures reported in the present Tariff Commission study, and allowing 6 per cent interest on invested capital, it becomes apparent, as indicated in the tabulation below, that the profit margin in 1941 was less than 8 per cent in the United States and 5 per cent in Texas, which appears low for an industry with as great a risk as petroleum production. Considering the higher prices in 1937 and the fact that costs were less than in 1939–41, the profit margin in that period was probably 12–15 per cent, or two or three times the current level. It is clear that producers can not be expected to assume the large risks of drilling more wildcat wells than ever before in order to develop new production if they can only expect to recover 6 per cent interest on invested capital.

TABLE XIII

	Texas					United States				
	Price $/Bbl.	*Cost* $/Bbl.	*6% Int. on Inv. Capital* $/Bbl.	*Profit Margin After Int.* $/Bbl.	*Profit Margin After Int.* % *on Capital*	*Price* $/Bbl.	*Cost* $/Bbl.	*6% Int. on Inv. Capital* $/Bbl.	*Profit Margin After Int.* $/Bbl.	*Profit Margin After Int.* % *on Capital*
1939	0.99	0.78	.174	.036	1.2	1.02	0.79	.162	.068	2.5
1940	1.00	0.77	.180	.050	1.7	1.02	0.76	.157	.103	3.9
1941 9 mos.	1.10	0.78	.179	.141	4.7	1.11	0.76	.156	.194	7.5

3. The Tariff Commission report gives no consideration to the increasing cost of finding oil. While it is extremely difficult to determine the exact cost of finding oil for the industry, it is clearly apparent that this cost has at least doubled or tripled in the last few years, as the amount spent searching for oil has remained constant or increased, and the new discoveries have declined to 25 or 50 per cent of normal.

4. The study of costs admittedly failed to secure information from many of the smaller operators whose costs are probably the highest in the industry. The average production of the 207,000 wells on which cost data were secured was 13.6 barrels daily in September, 1941, compared with only 10 barrels for all wells in the United States. This indicates that the 189,000 wells not covered in the study have an average production of 7.8 barrels daily, or 43 per cent less than that of the wells covered by the study. Naturally, the small producing wells with a high cost would be the first abandoned in a period of declining margins between price and costs.

The deficiencies, indicated in the preceding paragraphs, in the Tariff Commission cost study raise a serious question about the conclusion that a general advance in the price of crude is not warranted at this time. If excessive abandonments are to be avoided and new discoveries are to be stimulated, price increases appear desirable if not absolutely necessary. Furthermore, in order to correct prices for changed transportation conditions, certain adjustments should be made, which can be accomplished best by advances. Present ceiling prices are based on differ-

entials for quality and geographic location which existed in 1941. Since that time, there has been a sharp increase in the demand for crudes suited to the production of critical war products and a decrease in the demand of crudes producing large quantities of low-octane gasoline. Furthermore, there has been a major shift in transportation, which entirely disrupts existing differentials for geographical location. In normal times, the Gulf Coast was the dominant price market for crude and the various grades were competitive at that point, taking into account pipeline tariffs. Due to the loss of tankers, there has occurred a definite shift in movement north by pipe lines and tank cars. The cost of transportation from such areas as North Texas, East Texas, North Louisiana, and Arkansas, to the East Coast is now less than that from the Gulf Coast and Southwest Texas, whereas it was formerly higher by the differential in trunk-line rates to the Coast. Of the total production of 1,100,000 barrels daily in the northern portion of District 3, two-thirds moved south to the Gulf Coast in July, 1941, but less than 40 per cent moves south now. In this same period, the movement north increased from 13 to 41 per cent. Under these circumstances, a readjustment is required in price differentials for location and quality even if there is no general advance in ceiling prices.

Closely related to crude-oil prices as an incentive to exploration is the percentage-depletion allowance of the petroleum industry. This regulation permits a producer to deduct 27.5 per cent of his gross income, but not more than 50 per cent of his net, when computing income for tax purposes. In effect, it offers a bonus through lower taxes to the producer of crude oil on his successful ventures and helps to compensate him for losses on dry holes. Without such allowance, the income from new fields would go principally for taxes, and there would be little incentive for operators to gamble large amounts in the search for oil. If the odds are stacked against operators by taxes, as well as by risks of dry holes, the chances of maintaining adequate crude reserves will be reduced correspondingly. Therefore, it is important that this tax provision be retained.

CONCLUSION

The importance of petroleum products in modern warfare can hardly be overemphasized. The essential task of the petroleum industry of this country is to supply the petroleum products required by the United Nations for military forces, war industries, and essential civilian uses. The dominant position of the United States in the manufacture of aviation gasoline may be of decisive significance in the struggle for control of the air. The task of the petroleum industry is large, and the adjustments to wartime conditions are difficult, but the achievements to date justify confidence in a satisfactory future performance.

The industry has been fortunate in having a unique relation with Government through the Office of Petroleum Administrator. Without the coöperation and assistance of this agency, many of the industry's war problems would have been much more difficult. Given an opportunity through continued intelligent regulation by this and other Government bureaus, the petroleum industry should achieve all of the wartime goals set for it.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 27, NO. 7 (JULY, 1943), PP. 990-995, 1 FIG.

DEVELOPMENTS IN SOUTHEASTERN UNITED STATES IN 1942[1]

MISSISSIPPI GEOLOGICAL SOCIETY[2]
Jackson, Mississippi

ABSTRACT

At the beginning of 1942 geophysical exploration, leasing, and wildcat drilling continued in the southeastern United States at about the same pace as in the preceding year. Activity was stimulated at the close of the year as a new prospective oil-producing zone, the Massive sand of the basal Tuscaloosa formation, was discovered in widely separated areas of south Mississippi. The showing of oil in this new sand, although not having been evaluated at the close of 1942, held much promise for a rejuvenated geophysical leasing and drilling campaign for 1943, especially in the south Mississippi area.

The prospects for production in this sand gave the state added importance as a future oil-reserve area. Approximately all of the state south of the east-west line through Jackson may be classed as favorable for production from the Massive sand.

Tinsley continued to be the main source of production. Since its discovery in August, 1939, the state as a whole had accumulated production of 48,575,803 barrels, of which 47,632,294 barrels were from Tinsley.

The major oil companies continued geophysical exploration on a large scale in south Alabama, working areas previously under lease. Drilling activity was limited to the completion of six dry holes.

Drilling activity in Florida and Georgia was limited to two wells each. Florida showed much promise for future wildcat drilling, in that more than 700,000 acres of new leases were acquired by major oil companies during the year.

INTRODUCTION

During 1942 exploration, leasing, and wildcat drilling continued at about the same pace as in the preceding year. In the early part of 1942 there was a period of readjustment in which the petroleum industry aligned itself with the war effort. The diversion from normalcy thus resulted in a more or less restricted drilling campaign in this area. Unquestionably there would have been several more wildcat tests drilled if normal conditions had existed. Although most areas during the past year showed a decline in the number of wildcats drilled, forty-nine wildcat tests were completed in this area in comparison with forty-four in 1941.

EXPLORATION

Geophysical exploration of all types continued on a large scale during 1942. At the beginning of the year there were 17 seismograph, 10 gravity-meter, 4 magnetometer, and 5 core-drill parties in the area. At the close of the year there were 13 seismographs, 10 gravity meters, 1 magnetometer, and 4 core drills. Geophysical exploration for this area during the year totaled 1,654 weeks. The cost of this exploration work is estimated at $2,391,600. The greater part of this work was in west, central, southwest, and south Mississippi, south and southwest Alabama, west Florida, and south Georgia. The Humble Oil and Refining Company repeated the 1941 performance as the greatest user of geophysical instruments, employing the core drill, el-tran, gravity meter, magnetom-

[1] Presented by title before the Association at Fort Worth, April 7–9, 1943. Manuscript received, June 15, 1943.

[2] This paper prepared by Urban B. Hughes, consulting geologist; J. B. Wheeler, Stanolind Oil and Gas Company, and R. Merrill Harris, The Union Sulphur Company, Inc.

eter, and seismograph for a combined total of 230 work weeks. The California Company, although having 231 work weeks, used only the gravity meter and seismograph, thus ranking second. The Carter Oil Company, the Pure Oil Company, the Atlantic Refining Company, and the Gulf Refining Company follow in the order named. Many large lease blocks were acquired as a result of this geophysical work. The California Company, the Carter Oil Company, the Humble Oil and Refining Company, and the Amerada Petroleum Company were the principal lease purchasers during the year. Additional geophysical crews are expected to be moved into the south third of Mississippi in 1943, undoubtedly creating a more active demand for unleased acreage, and stimulating wildcat drilling.

LEASING

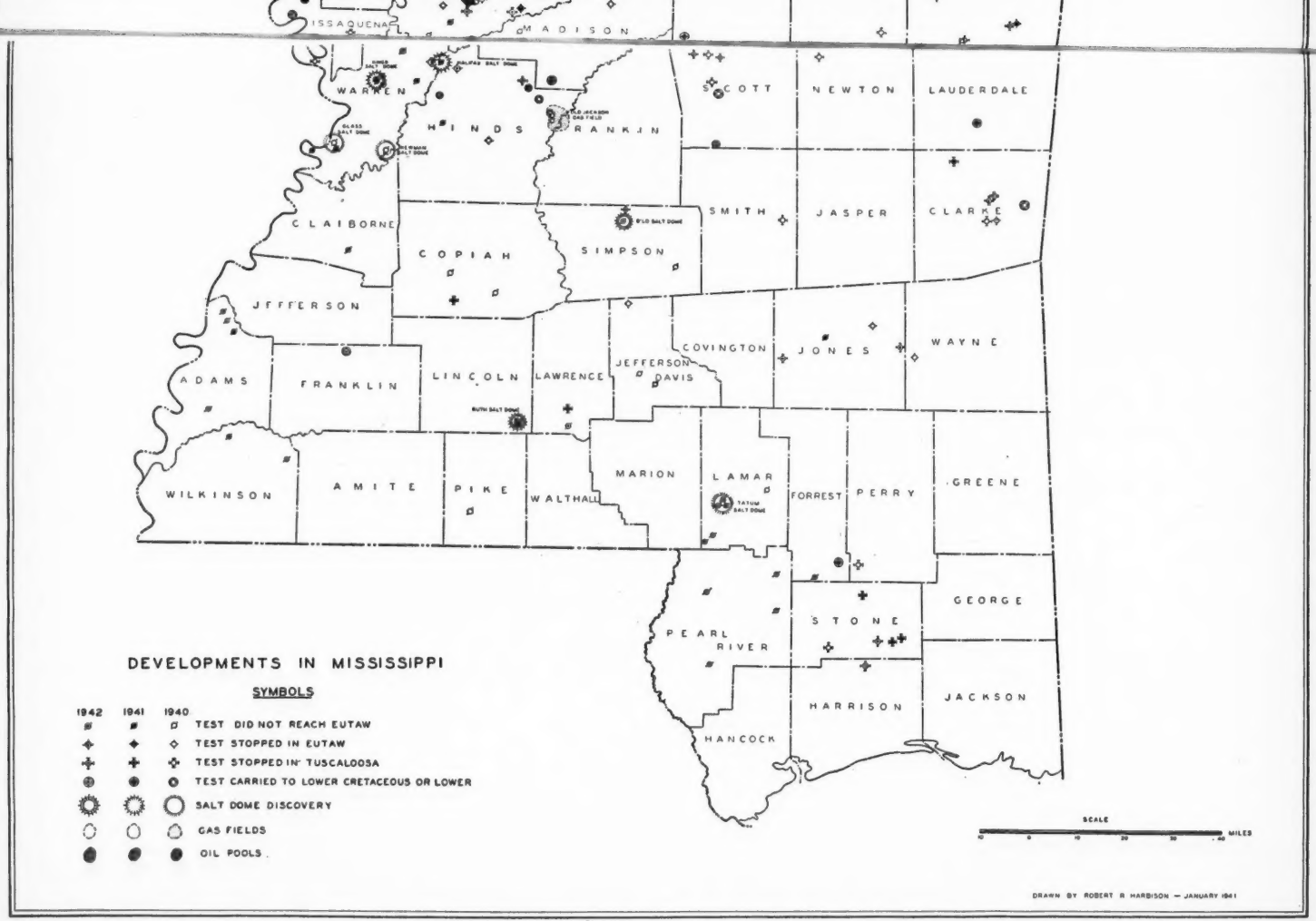
During 1942, 525,222 acres of new leases were acquired and 1,589,823 acres were released in Mississippi, not including new acreage leased or acreage surrendered by the Humble. In 1941, 742,510 acres were leased in Mississippi. At present, without exact figures available it may be assumed that the Humble Oil and Refining Company was one of the largest purchasers, if not the largest purchaser, of new leases in the state. Approximately 5,500,000 acres are estimated to be under lease in Mississippi, representing slightly less than one-fourth of its total area. Approximately 90 per cent of all 1942 acreage leased was in the south third of Mississippi. The average price was $1.00 per acre bonus for 10-year leases carrying an average of $1.00 per acre annual rentals. Excepting the Humble, the Magnolia Petroleum Company led the field in new leases purchased, having acquired 72,461 acres; the Carter was second, with 62,127 acres; the Gulf third, with 54,403 acres; and The California Company fourth, with 52,619 acres.

In Alabama, 11,002 acres of new leases, not including the Humble's acreage, were acquired, and 380,759 acres were released during 1942. This compares with 490,026 acres leased during 1941. A total of 1,233,027 acres of lands is now under lease in Alabama. This represents the acreage of all companies, with the exception of the Humble. The Sun Oil Company was the largest purchaser, with 4,294 acres, all being in south Alabama. The Superior Oil Company was second, with 2,749 acres, in the Warrior Coal Basin area of northwest Alabama.

In Florida 776,952 acres of new leases were acquired and 54,176 acres released during 1942. In 1941, 621,037 acres were leased. Assuming that the Humble has 1,500,000 acres under lease, the total leased acreage in the state approximates 3,686,140 acres. The Pure Oil Company, having leased 632,445 acres in the eastern Panhandle area of western Florida, was the largest lease purchaser. The Gulf, leasing in the same area, was second, with 125,432 acres. The average cost was $7\frac{1}{2}$ cents per acre.

In Georgia, acreage leased during 1942 totals 165,545 acres. Acreage cancelled totals 14,077 acres. The Sells Petroleum Company leased 144,600 acres, and the Sun leased 20,943 acres, this acreage being in south and southwest Georgia. The total acreage under lease in the state totals 483,071 acres.

DESOTO
MARSHALL
BENTON
TIPPAH
ALCORN
TISHO-
MINGO
TUNICA
TATE
PRENTISS
UNION
PANOLA
LAFAYETTE
COAHOMA
QUITMAN
PONTOTOC
LEE
ITTAWAMBA
TALLAHATCHIE
YALOBUSHA
CALHOUN
CHICKASAW
MONROE
OLD HOYT GAS FIELD
BOLIVAR
GRENADA
SUN-
FLOWER
LEFLORE
MONT-
GOMERY
WEBSTER
CLAY
CARROLL
OKTIBBEHA
LOWNDES
WASHINGTON
CHOCTAW
HUMPHREYS
HOLMES
ATTALA
WINSTON
NOXUBEE
SHARKEY
YAZOO
LEAKE
NESHOBA
KEMPER
ISSAQUENA
MADISON
SCOTT
NEWTON
LAUDERDALE


ISSAQUENA
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HINDS
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SCOTT
NEWTON
LAUDERDALE
CLAIBORNE
COPIAH
SIMPSON
SMITH
JASPER
CLARKE
JEFFERSON
ADAMS
FRANKLIN
LINCOLN
LAWRENCE
JEFFERSON DAVIS
COVINGTON
JONES
WAYNE
WILKINSON
AMITE
PIKE
WALTHALL
MARION
LAMAR
FORREST
PERRY
GREENE
PEARL RIVER
STONE
GEORGE
HARRISON
JACKSON
HANCOCK
DEVELOPMENTS IN MISSISSIPPI
SYMBOLS
1942 1941 1940
TEST DID NOT REACH EUTAW
TEST STOPPED IN EUTAW
TEST STOPPED IN TUSCALOOSA
TEST CARRIED TO LOWER CRETACEOUS OR LOWER
SALT DOME DISCOVERY
GAS FIELDS
OIL POOLS
SCALE
MILES
DRAWN BY ROBERT R HARBISON — JANUARY 1941

WILDCAT DRILLING

Forty-nine wildcat tests were drilled in Mississippi in 1942, totaling 284,499 feet of hole drilled, or an average of 5,806 feet per well. Depths range from 380 feet to 11,803 feet, and formations ranged from lower Tertiary to lower Mississippian. Thirty-eight tests were drilled either on surface, subsurface, or geophysical prospects, and eleven were merely promotional tests. Seismograph prospects led with twelve. The results were: no discoveries of oil or gas fields; the discovery of one piercement-type salt dome; ten high but dry, thirty-five normal, and three low tests. A few abnormally high tests were disappointing in that no new oil fields were discovered.

In Alabama six wildcat tests were drilled, with depths ranging from 380 feet to 6,618 feet and totaling 17,243 feet of hole. All tests were dry.

In Florida two wildcat tests were drilled, both dry, and in Georgia three dry tests were drilled.

PRODUCING FIELDS

Twelve new producing oil wells were added to the Tinsley field, Yazoo County, Mississippi, during 1942, bringing the total number of wells to 337 and producing, since its discovery in August, 1939, a cumulative total of 47,632,294 barrels. This 9,500-acre field, being defined on all sides, will yield, we estimate, an ultimate recovery of 90,000,000 barrels.

In the Pickens field, Yazoo County, Mississippi, no new wells were drilled in 1942. One well was abandoned. The two present producing wells are averaging 283 barrels daily, and the 40 acres have produced 621,589 barrels since the field was discovered in April, 1940.

The Pickens-Sharpsburg field, Madison and Yazoo counties, Mississippi, with seven producing wells averaging 1,407 barrels daily, has produced since its discovery in December, 1941, 311,022 barrels. This field is definitely a southeast extension of the Pickens fault-line field, and in the future the name Sharpsburg will be dropped. Additional producing wells will unquestionably be added to this field. Therefore, at the present time, we hesitate to offer an estimate on ultimate recovery for the Pickens field.

The Cary field, Sharkey County, Mississippi, remains a one-well field to date, averaging 11 barrels of oil and 400 barrels salt water daily. The present producing well is an offset to the discovery well, which is now used for salt-water disposal purposes.

CONCLUSIONS

Several million dollars were spent in exploratory work, leasing, and wildcat drilling during 1942 with the results that no new oil or gas fields were discovered. This failure to find new oil or gas reserves, although very disappointing, apparently did not break the spirit of the industry as a whole, for at the close of the year geophysical prospecting continued on as great a scale as in the preceding year, perhaps greater; leasing was accelerated, with higher prices being paid for

acreage; and the outlook for new wildcats was promising. This increased activity at the close of the year was motivated by the possibility of two new oil fields being discovered, one by The California Company in Lincoln County, Mississippi, and the other by The Pure Oil Company in Adams County, Mississippi. The favorable showings of oil encountered in these two tests, both being drilled on seismic prospects, have greatly stimulated interest in the productive possibilities of Mississippi, especially in the south third of the state. Inasmuch as these showings of oil were discovered in the lower Massive sand of the Tuscaloosa formation, a new possible producing sand for Mississippi has been found. This Massive sand is present in the entire south Mississippi area and where found on local structures may be expected to open new fields.

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GEOLOGICAL NOTES

SECOND-HAND BOOK DEALERS[1]

A. I. LEVORSEN[2]
Tulsa, Oklahoma

Following are second-hand book dealers located in various parts of the country who buy and sell geological publications and who are known generally to carry a larger than ordinary supply. If there are any additions or corrections, the list will be republished at some later date.

CANADA

MONTREAL
G. Ducharme, 995 Boulevard St. Lawrence, Montreal, Canada

OTTAWA
Thorburn & Abbott, 115 Sparks Street, Ottawa, Canada

TORONTO
The Albert Britnell Book Shop, 765 Yonge Street, Toronto, Canada

UNITED STATES

CALIFORNIA
LOS ANGELES: The Curio Book Shop, 719 West 6th Street
Darson's Book Shop, 627 South Grand Avenue
Holmes Book Company, 814 West 6th, and 333 South Main Street
Zeitlin & Ver Brugge, 624 South Carondelet Street

SAN FRANCISCO: Newbegins Book Shop, 358 Post Street

COLORADO
DENVER: Bargain Book Store, 406 Fifteenth Street
The Bookery, 527 Fifteenth Street

DISTRICT OF COLUMBIA
W. H. Lowdermilk & Company, 1418 F Street, Washington, D. C.

MARYLAND
BALTIMORE: Johns Hopkins University, Department of Geology

MASSACHUSETTS
BOSTON: J. S. Canner & Company, 665 Boylston Street

MISSOURI
KANSAS CITY: The Cramer Book Store, 1321 Grand Avenue
Kruse Bookstore, 1333 Main Street, Sta. B— P.O. Box 4352

NEW JERSEY
LEONIA: G. Schmidt, 353 Broad Avenue

NEW YORK
NEW YORK: Luther M. Cornwall Co., 261 Broadway
Henry George Fiedler, 31–33 East 10th Street
Paul Gottschalk, c/o Tice & Lynch, 21 Pearl Street
G. H. Stechert & Company, 31–33 East 10th Street
SCHENECTADY: James C. Howgate, 120 South Church Street

[1] Manuscript received, June 8, 1943.

[2] Consulting geologist, 221 Woodward Boulevard.

PENNSYLVANIA
PHILADELPHIA: G. H. Arrow, 218 South Fourth Street
Leary, Stuart & Co., 9 South 9th Street
PITTSBURGH: Walleck's Book Store, 903 Liberty Avenue

TEXAS
DALLAS: Arcadia Book Shop, 1301 Elm Street
Schmalzried's Book Shop, 911 Main Street

WASHINGTON
SEATTLE: Raymer's Old Book Store, 905 3rd Avenue
Shorey Book Store, 815 3rd Avenue

INTERPRETATION OF CABLE-TOOL DRILLING LOGS[1]

JAMES F. SWAIN[2]
Pittsburgh, Pennsylvania

The nation is becoming concerned with the declining rate of discovery of crude petroleum and natural gas, particularly in areas readily accessible to safe transport for war and industrial uses. It seems, therefore, as certain as it is logical that the geological profession will be called upon for an extraordinary effort to assist in the correction of this situation.

Anticipation of the coming demand is evidenced in the present and in the recent past by the preoccupation of geological societies and related organizations with a critical analysis of discovery methods and the results therefrom. Among methods particularly favored for more widespread and diligent application is the search for stratigraphic traps. This method is purely geological and lies primarily within the field of sedimentation. The success of this method depends on the quantity and quality of subsurface information available for study.

Several types of subsurface data are available to the geologist. Except in provinces unexplored by the drill, they are: cores, sample-study logs, electric and other physical process logs and driller's logs. The first two types afford direct lithologic determinations, the remaining types are indirect and require interpretation.

In order to interpret a driller's log the geologist should perceive the fundamental difference between this type of data and other types with which he is concerned. Whereas, core examinations and sample logs are described in lithologic terms which are essentially visual conceptions, the driller's log is derived, to a large degree, from experiences of the sense of touch. Even though his touch experiences are translated into simple words such as "sand," "lime," or "shale," these words have little meaning to him in the strict geologic sense for he is not dealing with conceptions of composition, structure, and origin, but of relative penetration, time, hardness, and abrasion.

[1] Manuscript received, May 17, 1943. Presented before Ohio Academy of Science, Columbus, April 30, 1943.

[2] Huntley and Huntley, Grant Building.

It is not possible to educe the true lithologic character of a section from the driller's data, but much useful information may be gained and much misunderstanding may be avoided if the rock names recorded by the driller are subjected to interpretation in retrospect, that is, traced back again to, and reconsidered solely as, the original perceptions which the driller experienced. In this way, the only known facts concerning a formation are susceptible to reconstruction and reinterpretation; the geologically questionable interpretation of the facts by the driller can be reconciled readily.

The means for interpretation in this manner becomes, therefore, simply the understanding of certain routine actions on the part of the driller and of the significance to him of their results.

The conceptions of penetration and hardness are conveyed to the driller by the action of the tools on bottom, an action which he "feels" by grasping the drilling cable or by holding on to the temper screw as it rises and falls with the motion of the beam. The "jerk" or "jump" of the drilling line on the immediate upstroke of the beam, if moderate denotes "softness," if severe denotes "hardness," and, as an indication of the effectiveness of the blow being struck on the bottom, signals, by its diminishing intensity, the need to "let out more screw," that is, to lower the bit to keep progress with penetration. Not too obviously these indications of penetration and hardness have somewhat more to do with frangibility or shattering under sharp impact and, conversely, the connotation of "toughness" than they have to do with hardness or softness in the geological sense. For example, the quality of brittleness exhibited by a rock composed of hard, thin laminations would induce rapid penetration; the rock would be considered "soft" and, if not abrasive, it probably would be classified as shale.

However, the most significant of the touch criteria used by the average driller are those that denote abrasion or lack of it. After the tools are withdrawn from the hole, the first action of the driller may likely be to feel, with his fingers, the face and cutting edge of the bit, in order to determine whether or not it is polished or roughened, battered or worn. The gauge may then be applied to the bit to determine whether the circumference is materially reduced by abrasive wear or "headed up," that is, expanded or "mushroomed" by the force of repeated blows on rock. Small particles of rock material, clinging to the bit, may be rubbed between the fingers to determine more fully the presence of abrasive grit. Continued doubt on this score may even be further resolved by biting a small cutting, thus enlisting the sense of touch of teeth and tongue.

Very often from these criteria alone much of a driller's log may be reconstructed. Keeping in mind, that he may also wash the cuttings occasionally and look at them, particularly when nearing a casing point or approaching the depth of a pay zone, the following touch perceptions of penetration, hardness, and abrasion may be literally translated from the more ordinary rock names used in the log.

Shale.—Rapid and regular penetration, moderate "jerk" of the drilling line, and a polished and unworn condition of the bit suggest shale. The suggestion is confirmed by a smooth, slightly soapy feeling of the rock particles when rubbed between the fingers.

Lime.—A slow rate of penetration accompanied by a severe "jerk" of the drilling line ordinarily indicates a hard type of formation. If the bit is "headed up" or battered out of gauge, but polished rather than roughened, and if the cuttings found on the bit feel neither gritty, nor smooth and soapy, the formation is logged as "lime." Geologists may believe this to mean limestone. It may be limestone, but a solid siltstone or a very fine sandstone will produce the same reaction and is invariably logged as "lime."

Sand.—A moderate rate of penetration and moderate "jerk" of the drilling line suggest a medium-hard rock. If the bit is appreciably worn out of gauge, if the beveled cutting edge is much worn, if the steel feels decidedly roughened or scratched and if the cuttings feel exceedingly gritty between the fingers, the formation is logged as "sand." It probably is a sandstone, but it could be a very cherty material or a very sandy limestone.

The "sand," "lime," or "shale" may be soft or hard, exhibiting a rate of penetration and jerk of drilling line interchangeable with the typical reactions just mentioned. Infinite variations occur, as we all know. However, the deciding factor will always be the degree and kind of abrasion. Indistinct abrasion characteristics may result in logging of sandy lime or sandy shale. This may mean merely that the grittiness is greater than to be expected from shale or lime, but not sufficiently apparent to warrant logging the formation as "sand." Samples commonly prove that the rock is shale with some coarse quartz grains or very fine sandstone that is not sharp enough to cut the bit in the characteristic manner.

The well known logging of "shale and shells" indicates a repetition of interruptions in a generally monotonous rate of penetration. Abrasion may be slightly perceptible and is attributed to the "shells." Samples show that formations, so logged, may be almost any combination of soft rocks interstratified with thin hard members. These may be harder shale or very fine sandstone flags. "Shale and shells" may be soft argillaceous limestone or soft dolomite with distinctly hard layers at short intervals. Shale and "lime" shells can be interpreted in character, the so-called shells exhibiting no appreciable tendency to cut or abrade the bit.

In addition to the rock names logged by the driller, the question of color is often a disappointment to one who is familiar with the geologic section. The muddy water which the driller observes, as he dumps the bailer after each run, provides the ordinary source of color determination. The soft clay rocks seem to be the principal ones capable of producing, in the water, a hue different from the ordinary monotonous gray. It should not be difficult to reconcile the apparent

disappearance of red rocks, for example, when it is realized that a few inches of gray or greenish shale may provide the driller's determination of gray color for a penetration of many feet of hard red shale or siltstone. Conversely, a few inches of soft red ochre-like claystone can mask the true color of many feet of gray rock. Comparisons of the driller's logs with corresponding sample logs reveal other similar instances of masked color.

In conclusion, it should be said that it is not intended to convey the impression herein that the driller relies exclusively on touch for his determinations. It is thought, however, that emphasis on that phase may be useful. The suggestion that interpretation be oriented toward a mental image of the driller's actual experience rather than of the lithologic name used, should lead to a realization that—considering the means and method at his disposal—the driller's log is the result of generally careful and creditable observation.

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DISCUSSION

GEOLOGICAL "UNION NOW"[1]

CAREY CRONEIS[2]
Chicago, Illinois

Fellow Geologists: We are gathered here at what most, if not all, of us hope will, in later years, prove to have been an occasion historic in the annals of American Geology. True, we have it within our power—within our magnificent capacity for inaction, within our selfish love of the *status quo*—to make this a funereal meeting—to make it in fact the wake of a sterile idea which fell on infertile soil. But it is also well within our imaginative and creative powers, here to lay the foundations for the renaissance of the Science—not the Society—to which we all *owe*, but unfortunately do not always *give*, our chief allegiance. If only we will exercise these latter powers, all of the not inconsiderable difficulties before us can be resolved, and there will come to be associated with this Fort Worth meeting all of that rich historicity with which we have properly clothed those rare but always fruitful occasions in which man has subordinated his individual differences in favor of a common cause.

A year ago, at the Denver meeting of the A.A.P.G., the speaker thought that he was probably playing Cassandra to the geological profession when he said in public what some geologists for years had been saying more succinctly, and much more picturesquely, in private.

Although some of you either heard the address in question or have read the paper on which it was based, let me, in order to provide the background for later discussions, briefly summarize what was said on that occasion.

THE DENVER RECOMMENDATIONS

I contended then, and still contend, that the profession of geology, because of its lack of unity in organization, and thus in direction, does not occupy as high a position in national esteem, *and thus in fundamental national utility*, as its potential importance warrants. I then cited a few of the extensive data which support my contention, and if time sufficed, could defend my thesis even more convincingly now. In order, therefore, not only to raise ourselves a few rungs higher on the ladder of scientific respect, but also to put our profession in a position to be of greater service to the nation, both in war and in peace, it was suggested that geologists:

I. Organize an American Geological Association to which each geologist, and, possibly, each person fundamentally interested in the subject, may belong, regardless of field of specialization, or prime professional affiliation.

II. Inaugurate and consistently support a system of awards to attract the highest grade of young men, and women, to the profession.

III. Establish and consistently maintain a series of rewards to honor outstanding accomplishments by members of the profession.

IV. Inaugurate and consistently maintain a unified, vigorous, and yet dignified public-relations program.

All of these suggestions are closely related; if the first were followed completely the remaining three could be readily facilitated, and within a few years some of our objectives would be in sight.

THE AMERICAN GEOLOGICAL ASSOCIATION

In discussing these four suggestions I said, in substance: Accepting the first recommendation means geological Union Now—Union Now in the Streit sense, not in the John L. Lewis connotation. Such a union is urgently needed, for in a period whose every news dispatch demonstrates the necessity of a federation of all men of good will and common purpose, too many geologists are still confirmed scientific separationists.

[1] Preliminary statement read at the organizational meeting for an American Geological Association held at the Hotel Texas, Fort Worth, Texas, April 10, 1943.

[2] Walker Museum, University of Chicago.

Although it is entirely your prerogative, not mine, to determine what form, if any, the A.G.A. is to take, one plan, suggested merely for criticism, follows. The A.G.A. should be made up of members of the G.S.A., the A.A.P.G. and its local affiliated societies, section E of the American Association for the Advancement of Science, the Paleontological Society of America, the S.E.P.M., the Mineralogical Society, the Society of Economic Geologists, the Society of Exploration Geophysicists, the American Geophysical Union, the Society of Vertebrate Paleontologists, the Association of State Geologists, the Association of College Geology Teachers, members of certain local geological societies, such, for example only, as the Boston Geological Society and the Boston Mineral Club, and certain members of various engineering societies, such as the A.I.M.E., and, possibly, some non-professional geologists genuinely interested in the subject. The academic base of individual membership should be broad, as in the American Chemical Society. Possibly it should be set no higher than the possession of a 4-year baccalaureate degree from an A.G.A. accredited institution, for, although there is legitimate difference of opinion on this point, I believe that some of the most important members of the Association might well turn out to be amateur collectors, school teachers, principals, and superintendents, executives of firms working with natural resources of geological import, various conservation enthusiasts, members of mountaineering clubs, inveterate travellers, and certain officers of local, State and Federal governments. The participating societies, under any scheme of organization that any one of us would be willing to support, would lose not one whit of their individuality, for the bindings of any proposed federation should not be tight enough to chafe, though they should be firm enough to preserve union and thus achieve the strength that only comes through unity.

The secretary, who might also serve as general editor of the A.G.A., probably would have to have at least semi-permanent tenure, but it will be essential that most of the officers be selected from the officers and councillors of the participating societies, possibly on some equalized revolving basis. This means a sort of geological "holding company"—perhaps "forwarding" company would be better for geology has already been held up in its progress far too long. Financial support of the A.G.A. could be secured through nominal dues from all members and proportional assessments on each of the participating societies. The proposed federation, with real support, would readily grow to a body, possibly with different grades of membership—of over 7,500 men, and 12,500 members is far from an impossible figure. It would not necessarily issue scientific journals in the ordinary sense, but it would publish a bulletin, possibly of *Science* format, possibly in modified *National Geographic Magazine* style. This bulletin, which might also be built into a source of revenue, should contain articles, illustrations, and items of interest to intelligent laymen and all members of the profession. It might well include certain addresses of general scope, news items of consequence to economic geologists, discussions of the use of geology and geologists in times of war and in periods of reconstruction, and reviews of general works whose interest crosses the lines of geological specialization. It might also serve as a journal of geological education and pedagogy, and would be frankly a geological "propaganda sheet" in the very best sense of the phrase. The Association might use *all* other standard media in reaching the public, and, in addition, it could perhaps issue automobile highway guidebooks in geology. In order to facilitate its work the Association probably should maintain a modest central office, preferably, but not necessarily located in Washington.

Standing committees of the A.G.A. could be the same as those which now are duplicated again and again in our present societies; but each participating society would have adequate representation on each of the central American Geological Association committees. Thus, at long last, one American geological hand might well discover, and facilitate, or at least not duplicate, what the other is doing.

One of the most important of these hypothesized committees might be that on Geology in National Affairs.[3] This group, without duplicating the efforts of the Federal or State geological surveys, would be charged with the responsibility of making geological information, ideas, and ideals available to the nation in times of peace as well as in periods of war. It does not seem to me that the potential advantageous war-time use of such information is even nearly so limited as has been suggested by some. But it would be the business of the standing committee to ascertain and disseminate the facts—not in a few months after a war is declared, or after a disaster eventuates, or when the exhaustion of a natural resource looms so imminent that all may see—but far in advance of any possible national emergency.

The Committee on National Affairs would also discuss such weighty matters as the substitution of women for men in the geological industries, especially during war times, would make certain general decisions as to the disposition of geological man-power during national emergencies, would consider such practical matters as training for all military men in topographic and aerial mapping and in map interpretation; and it might even discuss seeming geological impracticalities which imagination and vision can, in some cases, synthesize into realities.

The standing committee for studying the teaching of geology and the curriculum in the subject would, in time, probably be able to establish the teaching of geology in the high schools, and in the Military and Naval academies, not necessarily to recruit more persons to the field, though this may

[3] See the "First Report of the War Policy Committee of the American Institute of Physics," in *Science* (May 15, 1942).

become important in post-war days, but to broaden the base of understanding and support of our profession. Had we possessed truly national geological committees on curriculum and national affairs *last* year we would not *this* year be in the anomalous position of having what very little geology is to be taught to soldiers returning to the colleges masquerade under the heading, Geography. Although few may yet realize the seriousness of the situation, there will be practically no graduate schools of geology next year and very little undergraduate instruction in the subject. The roots of the geological tree, which, fortunately, still has a very sturdy trunk, are dying. We may in fact be on the threshold of an hiatus in the supply of younger talent from which the profession will not in a generation, fully recover. We should do something about it *now*.

For the good of the nation the time should be speeded when no State or Federal legislator—no military or naval officer—should be without some formal contact with geology. A really good high-school text in the subject, and an adequate Boy Scout Manual in geology, might be the opening guns in our campaign to re-establish geology as part of the secondary-schools curriculum so that our potential political leaders will have the chance to make that contact. In addition to seeing that such books are written and adopted, the Curriculum Committee might also play an important rôle in making some such test as the Graduate Record Examination standard for the evaluation and selection of geology students entering the graduate schools. For if the standing of the profession can be elevated—and there is no use trying to elevate its standing unless we also elevate its standards—and if, therefore, better men can be attracted to it, and if through standard tests, rather than through haphazard recommendations, we can definitely pick the best of the improved group, then the curriculum, important as it is, may possibly have less importance than we suspect. Good men will always be more valuable to the science of geology than good curricula, but, of course, we *must* have both. The A.G.A. would, I think, facilitate our *getting* both.

Finally, the A.G.A., in order not to be still-born, must be fathered by the present officers and councillors of the major geological societies; in order to grow from infancy to stalwart manhood, it must be mothered by *every* geologist, regardless of the scientific tag by which he likes to be identified.

My own, perhaps warped, views on the interrelated second, third, and fourth suggestions are too well, if not favorably, known to merit much reiteration. We must, I think, discover ways of attracting outstanding neophytes to the profession; we dare not any longer fail to keep pace with our sister sciences in rewarding our leading practitioners; and we are flagrantly derelict in our duty, not only to the nation, but to our geological forebears, if we do not, in *our* day, conduct our public relations in such a fashion that we again raise the geological standard as high among the other scientific banners as once did those older geologists. It would be less than candid, however, should I fail to point out that there are not only those who disagree violently with the contention that there is room for improvement of the standing of geology among scientists, laymen, and the military, but also those who doubt the wisdom of attempting to achieve such improvement, even were it theoretically desirable, through the four general procedures suggested. On the other hand, it is also perhaps fair to mention that those who are in substantial agreement with the broad outlines of my Denver recommendations are so numerous that unlike Cassandra, who despaired because she was destined never to be believed, I have been alarmed at the apparent near-unanimity of agreement with my contentions—alarmed because I realize full well that with vociferous approval there is always powerful silent as well as spoken criticism.

As a result of my Denver address on "Geology in War and Peace," and the presentation of a related paper, entitled "Geological Warfare," before many of the affiliated societies of the A.A.P.G., it has been possible for me to discuss the A.G.A. more or less *formally* with well over 1,000 geologists. Moreover, I have had the still greater privilege of conferring *informally* with no less than 100 of my professional associates. But what will, I think, impress you as far more significant is the fact that I have received more than 200 unsolicited communications directly or indirectly bearing on the American Geological Association, and that they are still coming in. Of these less than 2 per cent can be regarded as wholly condemnatory. Fully 9 out of every 10 letters are so completely in agreement with my contentions that I may with justification claim again, as I have before, that in my Denver statement I merely served as the mouthpiece for a large element of the geological fraternity.

Who, then, are these supporters of the concept of an American Geological Association? They are members of your own constituencies, but they represent no particular age group, no one subdivision of the science, no provincial section of the country. They are neither the altitudinous academicians, nor the professional professor pooh-hooers, not our chronically successful comrades, and certainly not the few consistently disgruntled members. There are enthusiastic letters of approval from youngsters in their twenties, and notes of dignified approbation from several celebrated "youngsters" in their eighties. The letters come from almost every part of this country and Canada, from South America, England, and the Pacific Islands; they come from young instructors lost in their specialties and from veteran professors who have almost forgotten theirs; they have been sent by young "sample grabbers" and by major officials of major corporations; they have been received from several past-presidents each, of most if not all of the organizations represented here to-day, as well as of the Geological Society of London. Last, but far from least, letters commending the Denver statement have come from privates in the Army, and from *the* past-president of the United States. This paper is theirs, not mine, and I only wish that it were practical to list them all as co-authors, for that is what they are.

Whether anyone likes it or not, therefore, it must be crystal clear that the concept of some sort of an American Geological Association is the idea, not of any one man, but of a large group of American geologists; and, whatever your own thoughts in this matter, the merits of the proposal, which has a swelling "grass roots" sort of support, must be judged with that fact firmly in mind. Furthermore, because there is, unfortunately, a suspicion in some quarters that I have some personal ax to sharpen in the matter of the proposed Association, I will try to lay the dust of this calumny by stating clearly that I am not to serve as any cog, however small, in the possible machinery of organization.

I wish that time sufficed for me to quote *in extenso* from this correspondence, the total of which forms a complete case history of the mental and physical ills of geology, and much of which is so penetrating that, in the interest of our science, I hope later to synopsize and publish the critical sections. But two points should be mentioned now: first, the fear in some quarters that active public-relations work can only mean bad publicity for Geology, and, second, the suggestion that the American Geological Association possibly should be patterned after the highly successful American Institute of Physics, or at least take a form somewhat different from that one I have tentatively outlined for discussion. Let me comment briefly on both of these matters.

The problem of achieving good publicity is indeed a difficult one, but the paradox is that those individuals who, like the Science of Geology, eschew public notice, commonly are the recipients of unflattering press comment. There has long been a clique in American geology which furthers the notion that to "promote" the subject in public consciousness is very much like "promoting" the sale of worthless securities. Geology, I contend with all of the strength at my command, represents sound values to the nation and we can, with as clear a conscience as the chemists, "promote" the subject in the first and third Websterian sense, to-wit, "to exalt in station, rank, and honor" and "to contribute to the growth, enlargement and prosperity of." Yet a distinguished West Coast geologist recently wrote me as follows; "I wish something could be done for poor down-trodden geology along the lines you suggest. At a geological luncheon last spring I spoke a few words in favor of popular pamphlets, but was given the 'bad eye' by several 'big shots'. The oldsters are set against publicity. We should place our hope in the younger men."

I disagree with my correspondent's last two lines. Resistance to a good public-relations program is not a function of age, it is a function of an attitude of mind. Those who grimly cling to that attitude comprise some of our leading geologists, and my best friends. Being my friends, they are not slow to point out that my long-continued efforts to unite geologists and provide adequate, honest publicity for the profession, are unwarranted, undig-

nified, and deleterious to the good name of geology. I counter by stating that, with only the best interests of our science at heart, they themselves may well be the unconscious saboteurs of the profession.

Does anyone for a moment dare to support the negative of the proposition that the American Chemical Society's publicity has been good for chemistry, chemists, and the nation? The more than 35,000 members of the Chemical Society are ably represented in magazine advertisements, on the radio, in industry, in the press, in education, in Washington, *and* in the Chemical Warfare Service. And for those very few geologists who are interested in mundane matters, let me cite the incontrovertable fact that at all stages of their professional progress the chemists receive an average wage which is far beyond the average geological recompense. The homely old adage, "The squeaking wheel gets the grease," proves its direct applicability here. The ex-King of England made the same point only slightly more elegantly when, in a speech before the Travel and Industrial Development Association of Great Britain and Ireland, he said:

> He who whispers down a well
> About the goods he has to sell
> Will never reap the golden dollars
> Like he who shows them round and hollers.

Please do not misunderstand me, I am not a "hollering" man nor do I think that geology should be "hollered" about. Our public-relations program should be astute, not assinine, quietly effective, not loudly repulsive. It should make each layman—each state and national legislator—gratefully aware of Geology as an efficient scientific public servant; each industrial administrator dealing with geologicals conscious of his organization's deficiencies if it does not have a well trained geological staff; each high-school and college administrator cognizant of the cultural, as well as the scientific values in geology as an integral part of his curriculum; each member of the military familiar with the fundamental aspects of Geological Warfare; each member of every peace commission and every planning board aware of the contribution geological knowledge can make to the solution of their own problems and those of the world; each non-geological scientist—properly proud of his own field as the best scientific field of all—ready to admit that geology is only slightly inferior to his own; each geologist, cognizant of the worth of all other sciences, nevertheless, proud as never before of his own, knowing its weaknesses and striving to correct them, sensing its great and growing strength, but resisting all urges to boast about it.

But I do feel like "hollering"—and so should you— when as recently, the American Cyanamid Corporation, in its "Molding the Future through Chemistry" series includes a full-page color advertisement entitled "Even Prospectors Are Chemists Now"; and when Spencer Lens Company, as recently as March 19, sponsors an advertisement entitled "The Microscope Enlists for War" and devotes the text to chemistry's undeniably significant rôle in the conflict, but with the illustration, giving life to the story, a properly labelled picture of a *petrographic* microscope. To counter these adverse bits of publicity our profession offered, inadvertently, of course, only the full-page testimony of the geologist who, even in Siberia, found that "Canadian Club" is an excellent whiskey.

Finally, I do feel like "hollering" with a Gargantuan roar when, as consultant to the National Defense Research Committee, in order to gain access to an army camp I must produce credentials which solemnly assert that I am—not a *geologist*—heaven forbid! but a *chemist*! Please do not misunderstand me! I was trained, in part, in that latter subject and am genuinely appreciative of chemistry and chemists. We must never be put in the position of seeming to improve the status of geology by attacking the well earned standing of our sister sciences. But the great American technological engine can not function smoothly, and deliver all its power to the nation, with the geological cylinder missing.

Wake up! Wake up, geologists, to the bad publicity which comes from having no

public-relations program at all. Realize, before it is too late, the fine results that, for example, can be accomplished through such simple means as The Pure Oil Company's recent short announcements concerning the work of various divisions of its family of employees. These brief statements, given just prior to the introduction of Mr. Kaltenborn, have mentioned geologists on several occasions. On January 19, 1943, for instance, the announcer said:

> The Pure Oil Company presents . . . H. V. Kaltenborn, dean of American news commentators: [Brief pause] Modern war is waged with *oil*—oil for fuel, oil for lubrication. And wars are *won*, finally, by the side with the greatest *reserves*. That is why American petroleum companies are pursuing their constant search for new oil more vigorously than ever—that's why the work of Pure Oil geologists is more *important* than ever right now. You see, you can't just drill a well and strike oil. Oil is not found in a tank under the ground, or in an underground river or pond. Oil is found in the *pores* of rock. Holes must be drilled through the earth to get the oil out of this rock. Finding the proper place to drill so that the chances of locating oil may be greatly increased—that is a geological problem. As a result of geological work, Pure Oil has discovered some notable oil fields in recent years. To-day, exploratory work continues on all fronts so that America may have all the oil needed to win the war and ample reserves when victory is won. Now, for The Pure Oil Company—Here's H. V. Kaltenborn!

I contend that if any substantial percentage of American geologists considers such publicity as deleterious to our profession, not only ourselves but our country will suffer grievously for, to paraphrase Buckle's famous dictum, "When the interval between geologists and the public is too great, the former will possess no influence, the latter will reap no benefit!"

So much for the public-relations problem—now for a brief mention of the possibility of American Geological Association organizational procedures somewhat different from those tentatively outlined. One of these procedures which involves following, in part at least, the scheme successfully utilized by the physicists in organizing the American Institute of Physics, has been ably advocated by Paul Weaver in a letter to the executive committee of the A.A.P.G. This proposal, and several related ones which have merit, should be carefully considered by the organizational committee which, I hope, will soon be set up and at work.

This committee will also have to consider in detail the possible impact, upon our tentative plans, of Dean Edward Steidle's recent proposal to the A.I.M.E. for an entirely new program in Mineral Industries Education. Many of Dean Steidle's suggestions parallel those I made at Denver, some go far beyond—*all* must have our careful consideration. But let's dream no little dreams, let's not get bogged down in a mire of petty difficulties, let's not, like little men, say that the time is not propitious, that there are already too many societies—let us rather take courage from the paleontological parable, that the great things of earth always have found their origins during times of stress.

In conclusion, let me paraphrase from a letter written to the representatives of the A.I.M.E. by J. R. VanPelt. The choice was, with difficulty, made from a large number of letters crying to be read. But, finally, this one was chosen not only because Dr. Van Pelt so succinctly states what I hope is a majority viewpoint, but because his rich and diversified experience so peculiarly qualifies him to speak with authority. As many of you are aware, Dr. VanPelt is a mining engineer and geologist, who was once a teacher of our subject, and later the head of a college department of geology. He has long been active in the affairs of the A.I.M.E., is a past-president of the Western Society of Engineers, and has for many years been the technical director of the great Chicago Museum of Science and Industry. More important still, in proving the credibility of the witness, he took a significant part in the organization of, and occupied an important administrative post in, the Army Specialist Corps. Dr. VanPelt said, in substance:

In a nutshell, it seems to me extremely important that a new and aggressive geological organization of a broadly inclusive type should be formed.

A survey of the existing geological societies will show the impossibility of their covering the profession and representing it adequately before the public. The G.S.A. has elected to confine itself to an emphasis on "pure" research, and thereby has by implication abandoned to others the many aspects of applied geology, to say nothing of the field of public acceptance and recognition of geology. Furthermore, its exclusive methods of membership selection, and its large endowment, make it an ideal organization for the promotion of research; and it would seem unwise to spoil its special effectiveness by trying to make it too broad in scope. The A.A P.G. with its alert leadership and aggressive policies, has the right point of view but is obviously limited to persons engaged in petroleum geology. The Society of Economic Geologists likewise is limited to a specialized group, and in this case a rather small one. The A.I.M.E. is of interest only to those working in "applied" geology, and furthermore, geology is such a small factor, in the Institute as a whole, that it cannot serve as the recognized mouthpiece of the profession. All the other societies in the earth-sciences field, such as those representing mineralogy, paleontology, and geophysics, serve limited groups and cannot possibly accept responsibility for the profession as a whole.

The new association would benefit the profession in many ways. For instance:

1. It would draw the theoretical and practical geologists closer together, to the advantage of both groups. Those in "pure" geology would be brought more directly in touch with the basic unsolved problems of "applied" geology, and also would have closer contact with the data gathered by oil and mining companies. Those in "applied" geology would benefit by greater contact with the methods and the results of fundamental research.

2. It would encourage studies in the borderlines between the fields of the present societies.

3. It might provide additional publication outlets, especially in the borderline fields and in other areas now inadequately covered.

4. It would provide greatly needed avenues of public understanding of the profession. To some geologists the war has brought a great shock—the discovery that geology (a) lacks, and (b) needs, public recognition. They found out that the Army (and other groups as well) were oblivious to the profession, not from intentional stubbornness, but from practically unanimous ignorance about the profession. The Army knew about physicists, chemists, mathematicians, meteorologists, and even psychologists, and used them in large numbers. But geologists were not called for, either in Tables of Organization or otherwise. It turned out that the Army's idea of a geologist was an old codger dressed in a Prince Albert coat, thick spectacles, and a long beard, peering at pretty shells through a microscope. So when they wanted men who could interpret maps and air photos, they at first turned to architects! Which boils down to this: the geological profession needs to make itself felt. We don't find the physicists and chemists bashful about their profession, but it's sometimes a major "selling" job to convince a geologist that he can participate in telling a geological story without mortgaging his professional future. One of the biggest jobs of an inclusive Geological Association would be to carry on (within proper bounds, of course) the kind of promotional work that has made the public so appreciative of physics and chemistry. [End of quotation.]

Most of us have read, or at least heard of, the novel, *For Whom the Bell Tolls*. Not so many are aware of the poem from which its title was derived. Pointing out that all mankind is united in subtle ways and suffers a loss when any *one* man dies, the significant lines of the poem are—"Never seek to know for whom the bell tolls—it tolls for thee." So it is in a lesser fashion with geologists and geology—when, through lack of public understanding of our profession, any one of our associates loses, when, through failure to gain acceptance in the public consciousness, any of our many subdivisions suffers, we all unwittingly "die a little."

Fellow geologists, let us from this day, in dealing with the public forget that we are geophysicists, stratigraphers, paleontologists, engineers, professors, or industrialists, and join hands in an American Geological Association. If we do so, geology, now stumbling if not yet prone, will, like the giant Antaeus, rise from its contact with Mother Earth with strength redoubled.

ORIGIN OF THE CAROLINA BAYS[1]

DOUGLAS JOHNSON[2]
New York, N. Y.

In his comprehensive and very generous review of the writer's volume, "Origin of the Carolina Bays," John L. Ferguson[3] asks four questions which deserve answer. Although Ferguson agrees that artesian water certainly had its place in the history of bay evolution, he feels that evidence supporting the artesian phase of the writer's hypothesis of origin is weak to the extent that these questions are not adequately answered.

Because artesian activity was the first, and therefore for the most part a relatively remote phase of bay development, evidence of its existence is necessarily limited in quantity or indirect in character. Whether it is qualitatively weak is a matter of opinion which rests with the individual reader. The questions are herewith answered in so far as it is possible to answer them.

1. Why are the artesian conditions, which were theoretically active as the initial force in forming the bays, not active in the same areas now?

Evidence was presented to show that artesian conditions still exist throughout the bays area, great supplies of artesian water flowing from countless shallow wells, and from artesian springs functioning naturally at a limited number of points. In a few cases these springs are seen fountaining in the bottom of bays now in the lacustrine stage of development. Perennial streams flowing from bays now occupied by peat bogs suggest the presence of other artesian springs hidden beneath the bog deposits. It was recognized that such artesian springs are exceptional, since, according to hypothesis, and conformable to present conditions in the Coastal Plain, the incision of stream valleys has afforded opportunity for the waters to escape at lower levels on valley slopes and valley bottoms where conditions are unfavorable to the development and preservation of bays. Surface artesian springs could exist in vast numbers only so long as the flat Coastal Plain surface was undissected.

2. Why did the tremendous volume of water necessary to produce and maintain the bays under this hypothesis fail to develop prominent stream lines?

It is not believed that any abnormal volume of water was involved. Springs similar to those still existing are believed competent to produce the bays at a time when ground water level was essentially coincident with the undissected plain surface, and the surface sands were effectively saturated and thus readily mobile. Under such conditions a spring of limited volume could, it is believed, produce a shallow basin of very large dimensions, for reasons fully indicated in the text. While such artesian springs may have disposed of significantly greater quantities of water than now reach the rivers from ordinary springs and ground-water seepage, they need not have done so. Ultimately the outflowing waters did give rise to definite streams which incised their courses in the Coastal Plain, thereby ending the phase of maximum surface artesian activity. But on a surface as faintly sloping as that of the Coastal Plain the development and incision of streams must have been long delayed.

3. Why did not the puncturing of innumerable great holes in the impervious cap of the hypothetical artesian aquifer so reduce the hydrostatic head that artesian springs would fail to reach the surface farther down-slope?

The holes are not believed to have been of great size. On the contrary, they are believed to have been small as compared with the great diameter of the bays. While the

[1] Manuscript received, June 3, 1943.

[2] Columbia University.

[3] John L. Ferguson, Review of "The Origin of the Carolina Bays," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 27, No. 5 (May, 1943), pp. 654–56.

total number of openings may have been large, they represented but an insignificant proportion of the artesian area. Even where a single aquifer alone is involved, large numbers of artesian wells now flow at the surface. In the Coastal Plain, with its many outcropping lenses of permeable and impermeable beds, there was ample opportunity for artesian springs to flow from many different aquifers of local areal extent. The "patchy" distribution of the bays is in accord with the known structure of the Coastal Plain, and with the possibility that occasional aquifers did suffer exhaustion of artesian flow downslope from some bay areas.

4. How could a condition exist which would permit artesian water to rise abundantly to the surface through formations saturated with flowing ground water and yet permit an equally abundant outflow through sinkholes in the same saturated formations?

The situation pictured in this question does not correspond with the conception entertained by the writer. While it was recognized that outflowing waters through highly soluble formations may have given rise to sink topography, it was pointed out that the saturated surface formation is normally loose sand, in some places an imperfectly consolidated sandy loam. Removal of soluble formations below the surface might cause settling of the surface beds in which a typical bay was developing, thus imposing sink phenomena upon a basin topography resulting from artesian spring activity. Elsewhere solution of surface or subsurface beds by the descending waters of intake areas produced more typical sink topography. The best sinkhole areas appear to have been intake rather than outlet areas.

Let me take this opportunity to add a further word of explanation. Ferguson suggests that the magnetometer data adduced by some writers in support of the meteoritic hypothesis of bay origin might better have been dismissed with a single paragraph. The writer agrees insofar as the validity of such evidence is concerned. Unfortunately, he had to consider the fact that this evidence made a profound impression upon some able geologists, who might reasonably have criticized any summary dismissal of the magnetometer data.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

THE OIL AND GAS RESOURCES OF NEW MEXICO, BY ROBERT L. BATES AND OTHERS

REVIEW BY E. RUSSELL LLOYD[1]
Midland, Texas

"The Oil and Gas Resources of New Mexico," compiled by Robert L. Bates. 2d ed. *New Mexico Bur. Mines and Min. Res. Bull. 18* (Socorro, 1942). 320 pp., 35 pls., 23 figs. Price, $2.50, postpaid.

The first edition of "The Oil and Gas Resources of New Mexico" was prepared by the late Dean E. Winchester and published as *Bulletin 9* of the Bureau of Mines and Mineral Resources in 1933. Winchester quoted at length from earlier publications by N. H. Darton, particularly the " 'Red Beds' and Associated Formations in New Mexico," *U. S. Geological Survey Bulletin 794*, published in 1928. The present bulletin follows the general format of Winchester's bulletin but has been almost entirely rewritten.

Bates has enlisted the services of a number of geologists so that the volume is in effect a symposium, but unlike most symposia which are collections of individual papers on a common subject, the individual contributions in the present volume are carefully correlated and arranged in their logical sequence so that the volume is a unit with no undue emphasis on any subject.

The first main division of the book is a general discussion of the geography and general geology or, more properly, the general stratigraphy. Chapters on the Devonian system by Frank V. Stevenson, the Mississippian system by A. L. Bowsher and L. R. Laudon, the Pennsylvanian system by M. L. Thompson, and the Permian system of central New Mexico by C. E. Needham represent the results of recent research by the individual authors. Bates' discussion of the Permian system of southeastern New Mexico is a masterful summary of recent work by several geologists. Needham has contributed the descriptions of the Jurassic, Lower Cretaceous, and Tertiary systems while the treatment of the Cambrian, Ordovician, Silurian, Triassic, Upper Cretaceous, and Quaternary follow very closely (where not literally) the earlier descriptions by Darton. It is noteworthy that nothing has been added to the knowledge of the Silurian since Darton's descriptions in 1928, although rocks of that system are now producing oil in Ward County, Texas, and are the potential reservoirs of important future oil fields.

A chapter on geophysics and geochemistry contributed by B. I. Routh is a brief and very readable description of various geophysical methods of prospecting. In reading the chapter, however, the uninformed reader would get the impression that seismic methods of determining structure and electric logging of wells are nearly perfect. The author of this chapter apparently has had little experience with geophysical work in the Permian basin in which the most important of the New Mexico fields are located. It is true that both refraction and reflection shooting have been used and are being used very extensively in the Permian basin, and the results have been generally helpful, but far from universally successful. Electrical logging of wells has been tried by most of the larger oil companies but has been very generally discontinued except for special purposes. Nothing has been found in the Permian basin that will take the place of microscopic study of sample cuttings.

[1] Consulting geologist. Review received, April, 1943.

The U. S. Geological Survey in Roswell, New Mexico, is the only organization which relies on electrical surveys.

The bulk of the book is devoted to discussions of the oil and gas accumulations, their geology, development, and prospects for future development. Following Winchester, the state is divided into five areas for convenience of description. The Northwest area is described by B. I. Routh, the Northeast, Median, and Southwest areas by Bates and the Southeast area containing the bulk of the oil fields, by several individual authors. A comparison of the various discussions with those in Winchester's Bulletin brings out the tremendous advance in knowledge of the geology of oil resources of the southeastern part of the state and comparatively limited advance in other areas. Those who are familiar with the earlier publications by Winchester and Darton will recognize some old friends among the illustrations such as the surface structure map of the Esterito dome and a map showing the larger structural features of northeastern New Mexico. It would appear that practically all of the structures which could be mapped from surface outcrops were well known and had been mapped in more or less detail prior to the publication of Winchester's bulletin. On the other hand, surface work has added much to the knowledge of the stratigraphy, particularly of the Devonian, Mississippian, Pennsylvanian, and Permian systems.

Discussion of the Southeast area very properly occupies about 40 per cent of the volume. An introductory discussion of the geography by Bates is followed by a short but significant article by Ronald K. DeFord on the major structural features, accompanied by a paleogeographic map. DeFord introduces a new term, the Carlsbad shelf, which he properly recognizes as a part of the Delaware basin. The description of the Central Basin platform as a "ridge" is inapt; DeFord disclaims this term as an unapproved editorial addition.

The Artesia, Grayburg-Jackson, and Leonard pools and the Red Lake area of Eddy County are described by Bates. Other pools described in Eddy County are the Dayton pool by John Emery Adams, the Getty-Barber area by Neil H. Wills, the Loco Hills pool by Charles A. Aston, and the Shugart area by Robert E. Morgan.

In Lea County, Bates furnishes the descriptions of the Corbin, Hill, Lynch, Monument, North Lynch, Skelly-Penrose-Hardy, and West Eunice pools, and he collaborated with R. W. Miller in the descriptions of the Cooper-Jal and Langlie-Mattix areas. Other pools described in Lea County are the Arrowhead pool by R. L. Boss, Eunice pool by Edgar Kraus, Halfway pool by Ronald K. DeFord, Hobbs pool by R. G. Schuehle, Langlie Unitized Repressuring project by W. K. Davis, Maljamar pool by John A. Barnett, Salt Lake pool by Charles P. Miller, South Eunice pool by Delmar R. Guinn, South Lovington pool by John M. Hills, and Vacuum pool by J. C. Williamson.

The description of each of the pools follows a uniform pattern with paragraphs on location, history, stratigraphy, structure, reservoir rocks, fluids, drilling and production methods, production, and land ownership. The treatment of the stratigraphy is uniform throughout and follows the pattern set in recent papers in the *Bulletin* of the American Association of Petroleum Geologists. Nearly all of the papers are accompanied by subsurface maps and by illustrative cross sections.

It must be recognized that despite the numerous excellent papers that have been published in recent years on the Permian of Texas and New Mexico ther is still a considerable diversity of opinion on correlation, classification, and interpretation. The classification followed in the present volume is with minor exceptions that which has recently been generally accepted as the standard for the southwestern United States. Some minor exceptions may be noted.

The Glorieta sandstone is segregated as a separate formation instead of a member of the San Andres. Bates (p. 164 and Fig. 11) classes the Goat Seep as a back-reef formation equivalent to the lower part of the Capitan, although it was originally described as a reef

section below the Capitan. In Wills' discussion of the stratigraphy of the Getty-Barber area he mentions a wedge-shaped tongue of Castile anhydrite extending from the Delaware basin across the area. This is undoubtedly the Fletcher anhydrite which was described as a member of the Salado formation. If Bates and Wills intended to re-define the Goat Seep, Capitan, Castile, and Salado formations they should have been more explicit.

Bates (p. 164) correlates the San Andres with the Victorio Peak. As no definition of the top of the San Andres is presented, presumably that horizon is taken as the one commonly used in subsurface work. A suggestion of disagreement with this correlation is found in Williamson's description of the geology of the Vacuum pool; he says: "The Vacuum pool must be considered as a special case as it is in the zone of transition between the San Andres dolomite and the Delaware sand." The reviewer agrees with Bates' correlation of the San Andres with the Victorio Peak but if this is correct there can not be a transition from the San Andres dolomite to Delaware sand.[2]

Bates (p. 164) describes the difference in character between rocks deposited in the Delaware basin and contemporaneous rocks in the shelf or lagoonal areas. He emphasizes the presence of limestone reefs during Guadalupe time, separating the deposits of the basin area from those of the shelf areas but by inference eliminates similar reefs in Wolfcamp and Leonard time. King,[3] however, mentions reef deposits in the Leonard of the Sierra Diablo and a committee of the West Texas Geological Society, of which Bates was a member, refers to the Victorio Peak member of the Bone Springs formation as a limestone reef facies.[4] To the reviewer, the contrasting facies in the shelf and basin areas is strong evidence of marginal reefs separating the two and he would put the burden of proof on those who assert that such reefs are not present.

The oil in part of the Skelly-Penrose-Hardy area of eastern Lea County is produced from a sandstone known locally as the Shipley sand, near the top of the Grayburg formation (pp. 261–62). The Shipley sand is named from the Shipley pool in Ward County, Texas, and most geologists correlate the sand in the Shipley pool in the Queen formation. This difference in classification is another illustration of the fact that not all geologists are agreed on the correlation and classification of subsurface rock units.

The present volume contains 320 pages as compared with 223 pages in the earlier edition by Winchester. In Winchester's edition only 43 pages were devoted to southeast New Mexico while the present volume has 124 pages on that area.

Much space is saved in the present volume by the elimination of drillers' logs many of which were quoted by Winchester and still more by Darton. These served their purpose but practically all the correlations in the present volume are based on detailed microscopic study of well cuttings.

As stated by Bates in the introduction to the volume, the bulk of detailed geologic information relating to oil and gas in New Mexico is in the hands of oil companies. That this is true is a sad reflection on the State of New Mexico and on the Federal Government because a large percentage of the producing wells in the state are on lands owned either by the State or by the Federal Government. Leases in the Vacuum field are entirely on State-owned land. In the Maljamar field, 92 per cent of the wells are on Federal leases

[2] *Editorial note by Robert I. Dickey, Forest Development Corporation, Midland, Texas.*—If I had been the reviewer of this bulletin, the above sentence would have read: "The reviewer agrees with Williamson's correlation of the San Andres with the Delaware sand (middle), but if this is correct the San Andres can not be correlated with the Victorio Peak." Perhaps it should be stated that Williamson is not alone in his correlation even though the reviewer would cast his lot with Bates.

[3] Philip B. King, "Permian of West Texas and Southeastern New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 4 (April, 1942), p. 570.

[4] West Texas Geological Society Committee, "Résumé of Geology of the South Permian Basin, Texas and New Mexico," *Bull. Geol. Soc. America*, Vol. 53, No. 4 (April, 1942), p. 549.

and 8 per cent on State leases. Monument has 41 per cent State leases and 40 per cent Federal leases, Eunice 61 per cent State and 20 per cent Federal. Aside from any scientific considerations, it would obviously be to the advantage of both the State and Federal Government to maintain well staffed geological organizations to collect and study data pertaining to the oil and gas fields. There is not even a provision for the collection and preservation of samples from wells and these are the basic *sine qua non* for any sound geological investigations of subsurface conditions.

One of the most valuable features of the volume is the collection of subsurface maps and cross sections of Eddy and Lea counties. Thirty-five plates and 23 figures are included, most of which are maps or cross sections. One unfortunate mistake was made by the printer in transposing two cross sections. Plate No. 16, labeled a cross section of the Grayburg-Jackson pool, is in reality a cross section of the Vacuum pool, while Plate 35, labeled a cross section of the Vacuum pool, is actually a cross section of the Grayburg-Jackson pool.

One new stratigraphic unit is named and defined. This is the "Lovington Sandstone Member of the San Andres Formation," described by John M. Hills on pp. 270–71 in his discussion of the South Lovington field.

LANDSCAPE AND CLIMATIC ACCIDENTS, BY C. A. COTTON

REVIEW BY BURTON WALLACE COLLINS[1]
Auckland, New Zealand

Landscape as Developed by the Processess of Normal Erosion, by C. A. Cotton, professor of geology, Victoria University College, Wellington, N. Z. xviii +301 pp., frontispiece + 44 pls., 214 figs. Cambridge University Press (1941). Price, 33s.(N.Z.)

Climatic Accidents in Landscape-Making, by C. A. Cotton. xx+354 pp., colored frontispiece +58 pls., 149 figs. Whitcombe and Tombs Limited, Christchurch, N.Z. (1942). Price, 30s.(N.Z.)

"Epoch-making" is probably not too strong a word to apply to these two recent books by Professor Cotton of the University of New Zealand, though perhaps "epoch-*marking*" might be a better term. The epoch they mark, in the opinion of the reviewer, is that stage in the growth of the science of geomorphology when this branch of earth-science has itself developed sub-branches.

In the preface to *Climatic Accidents* (which bears the dedication: "To the memory of Willard D. Johnson. The landscape was to him an open book") is the keynote of all Professor Cotton's work: "Few of the many problems touched upon may be regarded as solved; and discussion continues."

With this characteristic attitude as a background, Professor Cotton discusses rival theories fairly and offers alternative explanations of geomorphic processes and products.

Some of the ways in which geomorphology may assist or interest the petroleum geologist were touched on in a previous review of another of Cotton's books. Of the two works here considered *Landscape* will probably be of more use from a practical point of view, as in it are discussed the "normal" processes of erosion—those which have been effective in the production of the majority of sediments and of fossil landscapes (unconformities) as well as of most present-day landscapes (or at least the major features of such landscapes) in actual and possible oil-producing countries.

[1] P. O. Box 10, Auckland, New Zealand. Manuscript received, April 26, 1943.

After an introductory chapter, *Landscape* deals with "Mass Movement of Waste" and "Rain and Rivers" (Chapters II and III). The concept of the cycle of erosion is then introduced and discussed very fully (Chapters IV to XVII), in the main following the well known scheme of Davis. The views of the continental school of geomorphologists (especially Walther Penck) are, however, given due consideration in the chapters on "Maturity of the Landscape; Subdued Relief-forms" (XIV) and "Peneplains" (XVII). It is of interest to note that "a quarter of a century ago the late Professor Davis for the author's benefit defined the limiting steepness of the slopes of a peneplain as such as one might lay out a straight road on in any direction 'and trot on it'." Professor Cotton adds that "in these days this would be a high-gear road."

Especially interesting chapters in this section of the book include "Subsequent Erosion on Folded Rocks" (IX), where the development of one-cycle and multi-cycle mountains and the adjustment of drainage to structure are discussed; "Transverse Valleys; Superposed and Antecedent Gorges" (XI); Chapter XIV (already referred to) where the views of Lawson and others on the origin of the convexity of ridge-crests in humid regions, and of razor-back divides in hot and wet (tropical) regions, are reviewed; and two chapters (XV and XVI) on "Constructional Land Forms; Aggraded Plains" and "Fans; Bahadas; Basin Plains; and Deltas."

"Resurrected Fossil Land Surfaces" are dealt with in Chapter XVIII, which should be of particular interest to geologists as dealing with unconformities from the geomorphological standpoint. Intersecting peneplains (the "Algonkian wedge" of the Grand Canyon section) and "morvan" landscapes are also here described.

The next section (Chapters XIX to XXIII) deals with interruptions of the normal cycle. "Effects of Uplift and Warping" (XIX), "Positive and Negative Movements of Base-level" (XX), "Block-faulted Landscapes" (XXI), "Fault Scarps" (XXII), and "Erosional Features Related to Fault Lines" (XXIII) are the chapter headings. Of interest to structural geologists is the statement in the last-mentioned chapter that "it is impossible to over-emphasise the importance of distinguishing with meticulous care between fault-line scarps and fault scarps, thus avoiding the possibility of introducing grave errors into interpretations of geological history from surface forms."

The last chapter (XXIV) in the book describes "Limestone Landscapes."

Each chapter is written as a unit, in a clear flowing style without paragraph or section headings (thus avoiding the didactic or "examination complex" impression given by the majority of textbooks). A reasonably full index facilitates reference to any subject not mentioned in the chapter headings, as well as to the names of authors quoted or referred to in the numerous bibliographical footnotes, and to localities mentioned in the text.

As in Professor Cotton's earlier book, and in most of his papers, the illustrations are a noteworthy feature of the work. Line drawings, including block diagrams, sketch maps, and pen-and-ink sketches of landscapes and landforms (many original) are scattered throughout the text, while the photographic illustrations (86 in number) are grouped on 44 plates at the end of the book. The reproduction is excellent and the subjects well chosen, landscape features from many parts of the world being represented in both drawings and photographs. The arrangement of the plates, while probably of benefit to the printers, is not without disadvantages to the reader, however. The reviewer, while reading the book, found himself compelled to use two book marks and often wished he had three, since in order to find out the source of a photograph it is necessary to refer to the list of plates at the beginning of the book. Constant turning of pages wastes time and becomes annoying. The photographs could have been acknowledged as to source on the plates themselves, and the seven pages of the list of plates (duplicating the descriptions beneath each photograph) eliminated altogether. By the way, as a general criticism of many books, if a list of plates, why not also a list of text figures? In the present case the latter would seem more

necessary (though lacking) since the figures are scattered while the plates are grouped. It may be mentioned that a large number, probably the majority, of the illustrations are different from those in Professor Cotton's *Geomorphology*.

Climatic Accidents described in the title page as a sequel to *Landscape*, is divided into two sections: I, "Dry and Dry-seasonal Climatic Landscape Types" (pages 3–100) and II, "Glaciated Landscapes" (pages 101–343). The book is uniform in page size and arrangement with *Landscape* (and also with *Geomorphology*), and is written in the same unbiased, lucid, careful style. Limitations of space preclude a detailed analysis of the contents (this review is already over-long), but a few points may be mentioned.

In the first section subjects of particular interest include: a full treatment of "The Landscape Cycle under Semi-arid Conditions" (Chapter III), "Piedmont Slopes and Lateral Planation" (IV), and "Sheetflood Erosion or Rockfloor Robbing" (V). The various phases of pedimentation are fully discussed. "African Inselbergs and Plains" are dealt with in Chapter VII, while Chapter VIII is devoted to "The Savana Cycle"—the "savana climate" being described as "characterised by an alternation of wet with rather long dry seasons in which high temperatures occur; so that vegetation is scanty except along water courses."

The fifteen chapters of the second section (X to XXIV) contain a very comprehensive account of glaciation and its results for the study of which New Zealand forms an almost ideal field, with large active glaciers in the Southern Alps and the effects of a greatly intensified Pleistocene glaciation obvious over a large part of the South Island. Examples are drawn, as in the cases of all other subjects treated, not only from New Zealand but also from most other parts of the world where the features in question are found.

Bibliographical footnotes are again numerous (45, for instance, in the chapter on African inselbergs). A few misprints occur here, perhaps more the fault of the proof-reader than the author. For example, Blackwelder's paper on "Yardangs" in the *Bulletin* of the Geological Society of America, Vol. 45, is dated 1933 on page 6, and 1934 on page 7. The title of W.D. Johnson's paper in the *Journal of Geology*, Vol. 12, 1904, is given as "The Profile of Maturity in Alpine Glaciation" on page 134, "The Profile of Maturity in Alpine Glacial Erosion" on page 160, and as "Maturity in Alpine Glacial Erosion" on page 178. These, and a few other similar small inconsistencies and inaccuracies, contrast strikingly with the generally high standard of meticulous care evident throughout both books. They are probably due to the publishers' difficulties in checking with the originals in a country so poorly supplied with libraries and catalogues as New Zealand. In all other respects, including the clarity of the type and the reproduction of the plates (but excepting perhaps the quality of the paper), *Climatic Accidents* (published by a New Zealand firm) compares very favorably with the Cambridge University Press' *Landscape*. The New Zealand book scores over its English brother in possessing a colored frontispiece and jacket. Another improvement is that the 117 photographs grouped on 58 plates at the end of the book are acknowledged on the plates themselves, though the entirely superfluous seven-page list of plates is still there.

The successful production of these two books (together with the same author's revised edition of *Geomorphology*) during a world war is a notable achievement, the author and his publishers all deserving congratulation. The author's postscript to the preface of *Landscape* (dated September, 1940) is worth quoting.

> It has been said that every textbook is out of date before it is printed. I believe this is an exaggeration; but, if a great lag in publication can be detected in the case of this book, some excuse for it may be found in the troublous times in which we live and in the long sea route by way of which manuscript and proofs must pass to and fro between Cambridge and the antipodes.

It is in fact rumored that the author's first set of corrected proofs of *Landscape* went to the bottom of the sea on their way to England. This may have been the reason for the

New Zealand firm's opportunity to show that a first-class scientific textbook of world interest can be produced in Lat. 44° S.

STRATIGRAPHY OF THE EASTERN AND CENTRAL UNITED STATES, BY CHARLES SCHUCHERT

REVIEW BY W. H. TWENHOFEL[1]
Madison, Wisconsin

Stratigraphy of the Eastern and Central United States, by Charles Schuchert. Cloth. 6×9 inches, xvii+1013 pp., 4 pls., 78 correlation charts, 123 text figs. $15. John Wiley and Sons, New York City (1943).

This, the second volume of a three-volume monograph on the Historical Geology of North America, treats of the historical geology and stratigraphy of the eastern and central United States as far west as the eastern boundaries of Montana, Wyoming, Colorado, and New Mexico. The first volume, published in 1935, considered the "Historical Geology of the Antillean-Caribbean Region, or the Lands Bordering on the Gulf of Mexico and the Caribbean Sea." A third volume will treat of the Historical Geology and Stratigraphy of Greater Arcadia (New England and the Maritime Provinces), eastern, central, and Arctic Canada, the islands north of Canada, and Greenland. The third volume is stated by Miss Clara Mae LeVene, the secretary of Professor Schuchert, to be well advanced toward completion and should be ready for publication when publishers are freed from wartime restrictions. It will contain an atlas of American paleogeography in which will be given Professor Schuchert's last and most mature views on the subject to which he devoted many years of his life.

When Professor Schuchert initiated the several-volume work on historical geology and stratigraphy, it was his intention to include all of North America. This very ambitious program was begun long after he had passed middle age, although it should be remembered that he had been studying the field intended to be covered for many years before. Within the past several years he began to realize that he was not likely to be spared to bring the work to completion. He decided to concentrate on the eastern and central parts of the continent and to leave the western part to some one of his successors.

In this second volume dealing with the stratigraphy of eastern and central United States, emphasis is placed on the Paleozoic. This is not stating that the Mesozoic and Cenozoic have been neglected, as this is not the case. Very little consideration is given to the pre-Cambrian and Pleistocene. Professor Schuchert did not greatly concern himself with these divisions and he therefore wisely left their consideration to those whose life work had been concerned with these parts of the geologic column.

The second volume is divided into an introduction and eight parts with a total of thirty-four chapters. Thirty-one states (the preface gives thirty) are considered in more or less detail. To the extent that parts of their areas are in the Atlantic Coastal Plain, the New England states are not considered. The treatment of the geology of each state follows a more or less similar pattern. There is an introductory part which gives an outline of the physiography and a short history of the development of understanding of the stratigraphy. This is followed by detailed description of the stratigraphic sequence with attention given not only to terms now in use but also to those which have become obsolete. Fossils characteristic of each division are named. This last division comprises most of each chapter in which the stratigraphy of a state is considered. The other two divisions rarely receive more than two to four pages except for the state of New York, where the introductory part relating to the physiography and the historical development covers a little more than thirty pages.

[1] Department of geology, University of Wisconsin. Manuscript received, April, 1943.

The chapter comprising the introduction to the volume is concerned with stratigraphic terminology, and the historical development of this terminology. Professor Schuchert's views are summarized and exemplified in two tables in the latter part of the chapter—one table dealing with rock and time terms, the other illustrating the application of the terms to a division of the Ordovician.

The New York section of the Paleozoic is considered at length in Part I. Since this section is rather generally taken as the standard of reference for the Paleozoic of North America, since the methods of mapping formations in North America seem to have been initiated in New York, since the Geological Survey of New York has left an impress on North American geology which is second to none, and since the use of fossils in geologic work seems to have been first fully appreciated in New York, very detailed consideration is given to the geologic section. There is a brief history of the development of stratigraphy in New York and much attention is given to the development of the principles of stratigraphic correlation, particularly by means of fossils. Each of the stratigraphic names now or formerly used in New York is defined and each name of a geologic division now in use is faunally documented. Maps show areal distribution of exposures, and columnar sections and charts indicate stratigraphic relations and correlations. Attention is called to the decided difference between the stratigraphy of eastern and western and central New York, and it is noted that eastern New York is on the eastern margin of the Appalachian geosyncline and has close geologic relations with the geology of Quebec and Acadia. The geology of New York receives more complete consideration than that of any other state, and 112 pages, about one-ninth of the book, are devoted to New York, whereas by contrast, the geology of Iowa receives only 23 pages. This difference is readily understandable, as the stratigraphy of New York is more complex than that of Iowa.

Part II considers the states which either wholly or partly lie over the Appalachian geosyncline. These are Pennsylvania, New Jersey, Maryland, Virginia, West Virginia, Eastern Tennessee, North Carolina, South Carolina, Alabama, and Mississippi. As the central theme of Part II is the Appalachian geosyncline, the stratigraphy of each state is considered in its relation to the geosyncline. In the consideration of the stratigraphy, such historical background is presented as seems necessary to place the stratigraphy in proper perspective in relation to modern interpretation. Charts, columnar sections, and maps give a visual picture of the stratigraphy and Professor Schuchert's interpretations. Part II contains ten chapters and is the longest part of the volume.

The historical geology and stratigraphy of the Atlantic Coastal Plain are considered in Part III, with four chapters. As most of the states of the Atlantic Coastal Plain also have some part of their areas in the Appalachian geosyncline, the Paleozoic stratigraphy of each is considered in Part II. The geology of the Coastal Plain is not described from the point of view of a single state, but the several states are grouped into northeastern, middle, and southeastern subregions and each subregion is considered in a separate chapter. A partial table of the contents of Subregion 1 shows something of the extent and nature of the treatment. This is as follows: the Coastal Plain of the New England States, Georges Bank off Cap Cod, Cape Cod District, Nantucket Island, Long Island, Evolution of Long Island Sound, Hudson River Submarine Channel, *et cetera*.

Part IV considers the states athwart the Cincinnati arch. These are discussed in five chapters which in order cover central and western Tennessee, Kentucky, Ohio, Indiana, and Michigan. As it was at Cincinnati, on this arch, that Professor Schuchert was born, spent the early years of his life, learned to collect and study fossils, first learned many of the principles of stratigraphy and the relations between the preservation and variations of organic remains and the rocks in which they occur, and since he probably had seen and personally studied every formation over the arch, one can imagine his pleasure in again traveling in memory over the scenes of his early days in geology.

Part V treats of Illinois, Missouri, and Iowa in three chapters, as the states around the Ozark dome. It is to be noted that it was in the Ozark dome that the type section of the proposed Ozarkian system and period was described. Professor Schuchert discards the term, thus following the work of most other American geologists who are familiar with the area. The reviewer is inclined to criticize the association of states in this chapter and to wonder why some other states were omitted. It would seem that there is more justification for association of Iowa with Wisconsin or with Kansas than with the Ozark dome, as Iowa is on the southwest flank of the Wisconsin arch and to a larger extent lies in the Iowa-Kansas-Oklahoma coal basin. Why also is Arkansas omitted here and placed with Oklahoma and Texas? It is closer to the Ozark dome than is Iowa. However, the reviewer fully appreciates that assignment of a state to an orographic unit is by no means easy, as the political boundaries bear little relation to geologic features and most states straddle several such units. This is illustrated by Kentucky, whose eastern part is over the western side of the yet unfolded part of the Appalachian geosyncline, its middle part over the Cincinnati arch, a part of its western half over the southern extension of the Illinois coal basin, and its extreme western part on the eastern flank of the Ozark dome. Professor Schuchert was faced with the necessity of some association and somewhere a Gordian knot had to be cut.

Wisconsin and Minnesota are considered in the two chapters of Part VI as the states of the Upper Mississippi Valley. This is the shortest part of the book and covers only 39 pages. The reviewer considers that Iowa might have been properly referred to this part, and also the upper peninsula of Michigan. The latter certainly straddles the Wisconsin arch and the former is on the southwestern flank.

Part VII considers North Dakota, South Dakota, Nebraska, and Kansas as the Eastern Plains states in four chapters, one for each state. Professor Schuchert had seen few of the sections in any of these states and hence had little intimate field knowledge of their local columns.

Part VIII, with four chapters, treats of the states north and west of the borderland of Llanoria, the old deeply eroded land beneath the coastal plain of Texas and Louisiana. One chapter considers the land of Llanoria, the Llanorian geosyncline, the foreland, and the late Paleozoic "Oklahoma Mountains" of the Llanorian geosyncline, and the three following chapters describe the stratigraphy of Arkansas, Oklahoma, and Texas.

Four plates give reproductions of photographs of leading American geologists. The first plate (frontispiece) gives the pictures of geologists whose work has been largely concerned with the geology of New York, Pennsylvania, Virginia, and West Virginia. Plate I has the pictures of men whose life work was largely concerned with the Atlantic and Gulf states. Plate II has the pictures of geologists whose life work centered in the central states, and Plate III those who worked over the states from Texas to the Dakotas. Only one living geologist, C. N. Gould of Oklahoma, is included. Many prominent American geologists whose work rivalled, or was greater than, some of those selected are not shown. No reasons are given and there need be none, as the author evidently selected men whose inclusion in the illustrations seemed necessary to him. The reviewer regrets that Professor Schuchert's own photograph is not given as he certainly added greatly to understanding of the geology of much of the eastern and central United States.

If one were adequately to review this book, more than one entire number of the *Bulletin* would be required. The work is really an encyclopedia on eastern North American stratigraphy. Nothing like it has ever been brought to completion for so large an area. It is not too easy to read, as is also the case for any work of an encyclopedic nature, but, on the other hand, statements are direct, and there is no difficulty of understanding. The volume is well documented as to authorities, but the reader must search the bibliographies of geology to ascertain places of publication. There are few references given in conventional manner. This evidently was done in the interest of economy of space, otherwise the book would have been unwieldy in its expansion.

This second volume is essentially a work of reference which can not be otherwise than indispensable to every American stratigrapher. The reviewer considers that it should be close at hand on the desk of every geologist interested in the geology of the thirty-one states considered. It should certainly be close to those who do not have access to large libraries on geology. In the short time since the book came to the desk of the reviewer it has saved him many hours of searching for stratigraphic information. A most important part of the book is in the 78 charts which present Professor Schuchert's views in the important field of correlation. In reaching conclusions respecting correlations he had the advantage of access to the correlation charts in preparation by the Division of Geology and Geography of the National Research Council and his charts thus become doubly valuable as one may learn wherein Professor Schuchert's views are not in agreement with those of others. Also important are the many text figures of which some are columnar sections, others are regional sections, and still others are maps showing distribution of stratigraphic units. Several maps show structural relations. In spite of the fact that the book is a large one, it nevertheless may be said that it is *multum in parvo*. The reviewer recommends that every geologist concerned with the geology of eastern United States arrange to have access to this book.

GEOMORPHOLOGY, BY NORMAN E. A. HINDS

REVIEW BY HENRY A. LEY[1]
San Antonio, Texas

Geomorphology: The Evolution of Landscape, by Norman E. A. Hinds, associate professor of geology, University of California. 894 pp., 6×9 inches, many illustrations. Geology Series, Prentice-Hall, Inc., 70 Fifth Avenue, New York (1943). Price, $5.00.

Geomorphology, in the words of its author

> . . . tells how the face of the earth has come to look as it does today. It tells also of some of the facial changes which have occurred during the long past. It is written as an introduction to landscape evolution. Its purpose is to give a better understanding of the world about us rather than merely to set forth the elements of a technical subject required for credit in a college course. Therefore, some of the technical terminology has been replaced by understandable equivalents, even though these equivalents may appear more cumbersome. Many details have been omitted in favor of briefer, more concise discussions which should make the story easier to grasp. In short, the book is planned for the student and the general reader uninitiated, or nearly so, in earth lore. It is not written to inform those already expert in the subject. (Preface, p. VI.)

Geomorphology meets the need of a semi-popular treatment of landscape and its evolution for those who are curious about the diverse landscapes in which men live and over or above which they travel. It is a book of broad physiographic content in which present-day land forms are illustrated by many excellent photographs which are described in text that is clear and concise. There are 22 chapters, a bibliography, and index. The subjects and contents of the chapters are much like those found in textbooks of physical geology, physiography, and "geomorphology," but the text of each chapter is held within the intended semi-popular purpose of the author. Throughout the text all technical terminology is set out in italic letters. At the end of each chapter there are references to easily understood supplementary literature and lists of topographic maps illustrating the particular land forms discussed in the chapter. The bibliography at the end of the book is intended primarily for instructors, students, and professional workers in the field of geomorphology.

This book clearly is not intended to serve the growing needs of professional geologists, engineers, and geographers who are concerned equally with the large and small land units of the earth's crust, both surface and buried. The large units are beyond the faculties of

[1] Manuscript received, May 5, 1943.

direct inclusive observations as are also the buried units, whereas the small units lie within the field of human visions or the lens of a camera. The latter present-day surface land forms and the natural processes working thereon are well described and illustrated in this book. Consequently, notwithstanding the semi-popular purpose and scope of this book, professional workers will find it useful if only for the great number of photographs which the author has objectively selected from many original sources to illustrate the numerous land forms.

If a reviewer must be critical, a criticism of this book would center largely on the questions (1) that we know how the face of the earth has come to look as it does to-day, and (2) that it is either necessary or desirable to assign an age in present-day time units to natural phenomena. We do know many of the processes and agents of degradation and aggradation now at work actively carving and filling the face of the earth, but we are not at all certain how the large rock blocks, above and below sea-level, came to present positions. It is these large blocks that give form to the earth's crust and grandeur or monotony to their surfaces, that is, the mountains, plateaus, and plains. Concerning the second question we do know that the length of a day, a season, or a year, measured in present-day seconds, has remained constant throughout the existence of this planet. *Genesis* tells us that the earth and everything common to it were made in 7 days, but nowhere does it measure a second or define a day. The ancient philosophers may have been wiser and more discreet than the current-day scientists.

The author devotes 106, 98, 191, and 121 pages, respectively, to "Land Forms and Igneous Origin," "Evolution of Land Forms by Epigene Agents," "The Work of Snow and Ice," and "Land Forms Developed by Wind Action." Pertinent and basic statements of a geological nature are found throughout the book, for example, the following.

Page 351: All rocks in the outermost part of the earth can be weathered, and the shell of partly weathered rocks extends in places for several thousand feet beneath the surface.

Page 454: Distinction must be kept in mind between streams which are young, mature, and old and landscapes in the same stages. The classification of streams, as previously emphasized (pp. 446–452), is based upon the nature of their activity and the form of the valley which they erode; the classification of landscapes is based on the character of the topography of the area or region. As will later be shown, streams of various stages may flow in young, mature, or old regions.

Page 513: More commonly the crust is unstable, and such peneplains as are formed are of limited area. In recent geological periods, orogenic and epeirogenic deformation has affected most parts of the earth and in many places these disturbances are still in progress. As a result, few peneplains are to be found at the present time, though remnants of old, dissected surfaces of this type are not uncommon.

Page 754: At present very little old age limestone landscape is known.

Dr. Hinds is commended on the excellent quality of his work, both text and illustrations, which should advance the interests and satisfy the curiosities of laymen and students in landscapes, geology, and the associated sciences. This book is a distinct step toward popularizing geology—an activity which this Association fully approves and constructively furthers through two of its committees. It is indeed refreshing to find an author, frank and honest in his preface, who realizes the absurdity of 3-in-1 treatments of a subject which can not be written for the layman, student, and professional alike under one cover.

The 1940's may well mark a turning point in our approaches to the search for hidden vital natural resources. Cold necessity may compel us to reappraise both tools and thinking, clearly differentiate between tools and thinking, and above all bear in mind constantly that tools and thinking are never transposable in any sense, nor synonymous. In the coming renaissance, unless Fate decrees darkness, geomorphology will stand foremost with both applied and philosophical fields. Probably no science or branch of a science has lain more dormant in its applied economic aspects than has geomorphology. Its ultimate objective certainly is not restricted to the academic peneplains of Davis. It possesses dynamic potentialities which will become widely recognized as we become aware of the rôle and

economic values of buried land surfaces and earnestly seek to analyze the relationship between the land forms now viewed from the skies and their structural origins. The Pencks certainly stimulated the thinking of their critics, von Engeln has definitely advanced both the applied and philosophical aspects of geomorphology, and now Hinds gives us an illustrated reference record of the basic units in American nomenclature pre-requisite to competence in the field of geomorphology.

GEOLOGY OF KENTUCKY, BY ARTHUR C. McFARLAN

REVIEW BY JAMES H. GARDNER[1]
Tulsa, Oklahoma

Geology of Kentucky, by Arthur C. McFarlan. Published by The University of Kentucky, Lexington (1943). Price $4.50. Ten chapters, 531 pp., 116 pls., 42 figs. Red cloth binding. Dedicated to the late Dr. Arthur McQuiston Miller, predecessor of the author as head of the Department of Geology.

This book is an excellent credit to the author and also to the university. Profusely illustrated with photographs, sketch maps, charts and sections, the text is a full and dependable source of information with stress on the subjects of historical geology, structure, and stratigraphy. The contents are divided into six parts: (1) Stratigraphy, (2) Structural Geology, (3) Outline of Geologic History, (4) Regional Geology, (5) Natural and Scenic Features, (6) Mineral Resources, under which 104 pages are devoted to petroleum, natural gas, asphalt, and oil shale. A sizable bibliography lists by authors alphabetically the various subjects, places, and dates of publications on the geology of the state.

In Kentucky there is a wide range of stratigraphy exposed for students of geology. Truncation of the Cincinnati arch to a peneplaned surface and the deeper cutting of the Kentucky River gorge have exposed much of the Ordovician section, while on the flanks of the arch and in the adjoining basins the higher Paleozoics occur; in the west end of the state are found the Cretaceous and Tertiary sediments of the Mississippi embayment. The earth's sedimentary history involved in this part of the United States, as well as the structure and mineral resources in connection with it, makes an interesting and educational story which Dr. McFarlan from his long experience as a student and teacher has put together in a splendid contribution.

[1] Gardner Petroleum Company, Beacon Building. Review received, May 18, 1943.

RECENT PUBLICATIONS

ARKANSAS

Official Oil and Gas Map of Arkansas (1943). Scale: 1 inch = 5 miles. Sheet approx. 33×35 inches. In colors. Shows oil and gas fields, pipe lines, refineries, highways, railroads. Includes adjacent fields in Oklahoma, Texas, and Louisiana. Published by Oil and Gas Commission, Trimble Building, El Dorado, Arkansas. Price, $1.00.

CALIFORNIA

*"Five Points Area, Huntington Beach, California," by Wm. Ross Cabeen. *California Oil World*, Vol. 36, No. 7 (Los Angeles, 1st issue, April, 1943), pp. 16–17; 2 figs.

*"Earthquakes and Structure in Southern California," by Beno Gutenberg. *Bull. Geol. Soc. America*, Vol. 54, No. 4 (New York, April 1, 1943), pp. 499–526; 1 pl., 4 figs.

CANADA

*"The Oil-Fields of Western Canada," by Campbell M. Hunter. *Jour. Inst. Petroleum*, Vol. 29, No. 231 (London, March, 1943), pp. 75–88.

COLOMBIA

"Geological-Geographical Bibliography of Colombia," by José Royo y Gomez. *Inst. Colombiano de Petroleos Estudio Tecnico 3* (Bogota, November, 1942). 43 pp. In Spanish.

*"Report of the Minister of Mines and Petroleum to the National Congress in Regular Sessions of 1942," by Nestor Pineda. Vol. 1: XLI and 281 pp., illus. Appendix to Vol. 1: 347 pp., illus. 6.625×9.5 inches. Paper cover. National Printing Office, Bogota (1942). In Spanish.

GENERAL

*"Bibliography of Military Geology and Geography, First Supplement," prepared by Marie Siegrist (geology) and Elizabeth T. Platt (geography), for the Division of Geology and Geography of the National Research Council. *Geol. Soc. America* (419 West 117 Street, New York, January, 1943). 11 pp.

*"Oil Zones of the United States," compiled by *Oil and Gas Jour.*, Vol. 42, No. 2 (Tulsa, May 20, 1943). 2 pp. between pp. 68 and 69; map in colors.

*"Secondary Recovery Receiving Greater Attention," by Charles H. Rankin. *Petrol. Engineer*, Vol. 14, No. 8 (Dallas, Texas, May, 1943), pp. 90–98; 9 figs.

"Geology and Biology of North Atlantic Deep-Sea Cores between Newfoundland and Ireland," by W. H. Bradley *et al. U. S. Geol. Survey Prof. Paper 196* (March, 1943), pp. 157–163. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C. Price, $0.10.

"Bibliography of North American Geology for 1940 and 1941," by E. M. Thom. *Ibid., Bull. 938* (March, 1943). 479 pp. Sold by Supt. Documents, Govt. Printing Office, Washington, D. C., Price, $0.50.

*"Influence of Bacterial Activity on Source Sediments," by Claude E. ZoBell. *Oil Weekly*, Vol. 109, No. 8 (April 26, 1943), pp. 15–26.

*"Oil Shale and Shale Oil," by B. H. Weil and Whitney Weinrich. *Oil and Gas Jour.*, Vol. 41, No. 50 (April 22, 1943), pp. 48–55, 72; 2 figs., Vol. 41, No. 51 (April 29), pp. 73–79; 2 figs.

*"Oil Zones of the United States; Lower Mississippian," compiled by *Oil and Gas Jour.*, Vol. 41, No. 51 (April 29). 2 pp., between pp. 80 and 81; map in colors.

*"Discovery Thinking," by A. I. Levorsen. *Oil Weekly*, Vol. 109, No. 6 (April 12, 1943), pp. 11–17, 26; Vol. 109, No. 7 (April 19), pp. 14–17, 20; Vol. 109, No. 8 (April 26), pp. 12–13, 26; 15 figs. *Oil and Gas Jour.*, Vol. 41, No. 48 (April 8, 1943), pp. 38–46; 4 figs.

*"Problems of Exploration during the War," by E. DeGolyer. *Oil Weekly*, Vol. 109, No. 5 (April 5, 1943), pp. 39–41.

*"New Oil Reserves Must Be Found," by Alexander Deussen. *Ibid.*, pp. 47–48.

*"Geophysical Operations at Peak Levels during 1942," by E. A. Eckhardt. *Ibid.*, pp. 49–50.

*"Oil-Supply Problem Demands Early Solution," by Sylvain J. Pirson. *Ibid.*, pp. 51–56, 76–78; 3 tables, 1 fig.

*"Wildcat Drilling and Discovery Rates in 1942," by Frederic H. Lahee. *Ibid.*, pp. 57–70; 4 figs., 6 tables.

*"A Survey of the Nation's Oil Reserves and Needs," by W. B. Heroy. *Oil and Gas Jour.*, Vol. 41, No. 48 (April 8, 1943), p. 34.

*"The Geologist in the War," by Fritz L. Aurin. *Ibid.*, pp. 37, 62–66.

*"Wildcat Drilling in 1942," by Frederic H. Lahee. *Ibid.*, pp. 40, 68–76; 3 figs., 6 tables.

*"Some Factors Influencing Declining Rate of Crude-Oil Discoveries," by L. F. McCollum. *Ibid.*, pp. 41, 49–54; 4 charts.

*"Maintaining an Adequate Level of Geophysical Exploration," by F. Goldstone. *Ibid.*, pp. 56–61.

*"Oil Zones of the United States; Middle Ordovician to Devonian," compiled by *Oil and Gas Jour.*, Vol. 41, No. 48 (April 8, 1943). 2 pp. between pp. 88 and 89; map in colors.

*"Inspection and Analysis of Formation Samples," by Lester C. Uren. *Petrol. Engineer*, Vol. 14, No. 7 (April, 1943), pp. 72–76.

*"Compaction and Some Oilfield Features," by G. D. Hobson. *Jour. Inst. Petroleum*, Vol. 29, No. 230 (London, February, 1943), pp. 37–54; 5 figs.

Micromeritics, the Technology of Fine Particles, by J. M. Dallavalle. 428 pp., 82 tables, 100 figs., bibliography of 39 pp. 6×9 inches. Cloth. Pitman Publishing Corporation, 2 West 45th St., New York. Price, $8.50.

*"Revision of the Suborders, Families, and Genera of the Scleractinia," by Thomas Wayland Vaughan and John West Wells. *Geol. Soc. America Spec. Paper 44* (New York, March 12, 1943). 363 pp., 51 pls., 39 text figs., 47 pp. of references.

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*"Geologic Interpretation of Gravity Anomalies in the Southern New England-Hudson Valley Region," by Chester R. Longwell. *Ibid.*, pp. 555–90; 3 pls., 11 figs.

KENTUCKY

Geology of Kentucky, by Arthur C. McFarlan. 531 pp., 117 pls., 42 figs. 6×9 inches. Cloth. The University of Kentucky, Lexington (1943). Price, $4.50.

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MISSISSIPPI

*"Scott County Fossils. Jackson Foraminifera and Ostracoda," by Harlan Richard Bergquist. *Mississippi Geol. Survey Bull. 49* (1942). Reprint of Chapter on Fossils. 146 pp., 11 pls. Useful to petroleum geologists and paleontologists. University, Mississippi (1942).

*"Montgomery County Mineral Resources," by Richard Randall Priddy and Thomas Edwin McCutcheon. *Ibid., Bull. 51* (University, 1943). 115 pp., 18 figs., 2 maps.

OHIO

*"Flow Structures in the Berea Sandstone and Bedford Shale of Central Ohio," by John R. Cooper. *Jour. Geology*, Vol. 51, No. 3 (Chicago, April-May, 1943), pp. 190–203; 13 figs.

TRINIDAD

"The Analysis of Trinidad Crude Oils," by F. Morton and A. R. Richards. *Jour. Inst. Petroleum*, Vol. 29, No. 230 (London, February, 1943), pp. 55–74; 21 figs.

UTAH

*"Carboniferous Formations in the Uinta and Northern Wasatch Mountains, Utah," by J. Stewart Williams. *Bull. Geol. Soc. America*, Vol. 54, No. 4 (New York, April 1, 1943), pp. 591–624; 3 pls., 2 figs.

WYOMING

*"Critical Structures of the Gros Ventre and Northern Hoback Ranges, Wyoming," by Vincent E. Nelson and Victor Church. *Jour. Geology*, Vol. 51, No. 3 (Chicago, April-May, 1943), pp. 143–66; 10 figs.

"Geologic Map and Sections of Wertz Dome and Vicinity, Carbon, Sweetwater, and Freemont Counties, Wyoming," by W. B. Kramer and J. M. Cattermole. Scale: 2 inches = 1 mile. Pre-Cambrian-Cretaceous beds of the map area are described in *U. S. Geol. Survey Bull. 756* and *Bull. 796-D.* A few copies of map available, to those directly interested, from the director of the Geological Survey, Washington, D. C.; from Room 224, U. S. Customhouse, Denver, Colorado; or from Room 305, Federal Building, Casper, Wyoming. Description of map in *Geol. Survey Press Release* (May 26, 1943).

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Sedimentary Petrology* (Tulsa, Oklahoma), Volume 13, No. 1 (April, 1943).

"Stylolites: Primary or Secondary?" by Paris B. Stockdale.

"Detrital Minerals Derived from Recent Volcanics in Northwestern Chihuahua, Mexico," by Raymond Sidwell and Charles A. Renfroe.

"A Pipette Method of Size Analysis for the Centrifuge," by Stephen W. Dana.

"Sphericity Determinations of Pebbles and Sand Grains," by Willard D. Pye and Margaret Hurst Pye.

"Effect of Change of Wave Size on the Size and Shape of Ripple Marks," by O. F. Evans.

**Journal of Paleontology* (Tulsa, Oklahoma), Volume 17, No. 3 (May, 1943).

"Charles Schuchert, 1858–1942," by Carl O. Dunbar.

"Revision of Three Early Upper Cambrian Trilobite Genera," by Gilbert H. Raasch and Christina Lochman.

"Faunas of the Cambrian Cloud Rapids and Treytown Pond Formations of Northern Newfoundland," by B. F. Howell.

"Cephalopods from the Silurian of Arisaig, Nova Scotia," by Rousseau H. Flower.

"*Apsidoceras* in the Trenton of Montreal," by Rousseau H. Flower.

"Early Devonian Plants from New Foundland," by Erling Dorf and John R. Cooper.

"New Coelacanth Fishes from the Triassic of New Jersey," by Vincent E. Shainin.

"New Chester Corals from Alabama and Tennessee," by Wm. H. Easton.

"Marine Fauna of the Eastend Formation of Saskatchewan," by Loris S. Russell.

"Eocene (Capay) Corals from California," by Herdis Bentson.

"A Miocene Oreodont from Jackson Hole, Wyoming," by Edwin H. Colbert.

"*Fundulus sternbergi*, a Pliocene Fish from Kansas," by George M. Robertson.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 27, NO. 7 (JULY, 1943), PP. 1025-1026

THE ASSOCIATION ROUND TABLE

ASSOCIATION COMMITTEES

The list of Association committees, with the names of the chairmen and the members, is published in the June *Bulletin*, pages 876–78.

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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S. Morse Willis, L. Murray Neumann, Raymond D. Sloan

Frederick Glenn Fox, Moose Jaw, Sask., Canada
J. C. Sproule, W. C. Howells, Theodore A. Link

Connelly Edgar Hannum, Ardmore, Okla.
Jerome M. Westheimer, C. W. Tomlinson, John Marshall

Thad G. McLaughlin, Lawrence, Kan.
W. A. Ver Wiebe, Kenneth K. Landes, M. L. Thompson

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Frederick G. Phelps, Tulsa, Okla.
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Tom McGlothlin, Urban B. Hughes, Knight K. Spooner

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John Edward Brewer, Wichita, Kan.
George Putnam, Lee Cornell, Anthony Folger

Glen Lee Corrigan, Austin, Tex.
L. C. Snider, F. B. Plummer, H. H. Power

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F. A. Melton, V. E. Monnett, C. G. Lalicker

Darrel L. Kirkpatrick, Los Angeles, Calif.
James Gilluly, U. S. Grant, E. K. Soper

William Bradbury Leavitt, Tulsa, Okla.
John L. Ferguson, Andrew Gilmour, Dollie Radler Hall

Millard Holland Major, Corpus Christi, Tex.
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E. C. Pirkle, Jr., Decatur, Ga.
Arthur C. Munyan, Daniel J. Jones, Louise Barton Freeman
George Davis Reavis, Shawnee, Okla.
Charles E. Decker, C. G. Lalicker, V. E. Monnett
Ural A. Rowe, Houston, Tex.
Harry H. Sisson, George W. Carr, Louis H. Shearer
Eugene Evan Ruley, Parkersburg, W. Va.
F. M. Van Tuyl, J. Harlan Johnson, Dart Wantland
David M. Weber, Barcelona, Venezuela, S. A.
George L. Lockett, Hollis D. Hedberg, Paul H. Boots

FOR TRANSFER TO ACTIVE MEMBERSHIP

William Ernest McHugh, Wichita, Kan.
W. A. Ver Wiebe, E. R. Elledge, Howard S. Bryant

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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MEMORIAL

CHARLES SCHUCHERT
(1858–1942)

At the age of 84, with a full share of good works and honors, Charles Schuchert, world famous paleontologist and paleogeographer, died at New Haven, November 20, 1942. He was Fellow and Past-President of the Geological Society of America; member of the National Academy of Science; member of the American Association of Petroleum Geologists; recipient of medals from the Geological Society of America, National Academy of Science, and Academy of Natural Sciences of Philadelphia. He aided in organizing, and was the first president of the Paleontological Society. As to formal education, he had not so much as a high-school degree but was, nevertheless, Doctor of Science (honorary) from both Yale and Harvard universities.

The scientist who thus attained high ranking came from humble parentage. His father, Philip Schuchert, a cabinet maker, came to this country from Bavaria in 1855. His mother, Agatha Müller, also from Bavaria, came a year earlier. They met and married in Cincinnati. Charles, born July 3, 1858, was the first of a family of six children. The land of opportunity to which the emigrants had come so hopefully did not yield an easy living. Within a few years after their marriage, normal business was disturbed by the Civil War, and the father's job as cabinet maker came to an end. Without capital he set about to establish a cabinet factory of his own which was the source of the family income until the factory was destroyed by fire in 1877.

Educational opportunities open to Charles were limited. From age 6 to 13 he attended a parochial school and then, for part of a year, a business college. This ended his formal schooling. He had helped from time to time in his father's factory and at the age of 13 began full-time work in the varnishing room at 2 dollars a week and in 6 years advanced to general manager.

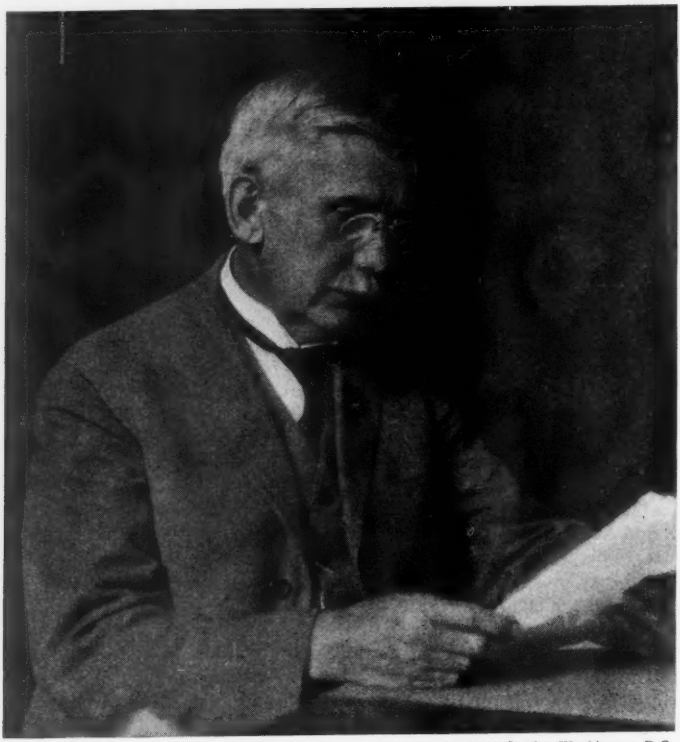
When the factory was destroyed by fire, the father, who was in ill health, became discouraged and responsibility for the family thereafter fell chiefly on Charles. With characteristic energy he began rebuilding a cabinet business and might ultimately have become an average or even prosperous business man, except for a second disastrous fire which completely destroyed the factory in 1884.

Although formal schooling had been limited, interest in scientific matters had not been wanting. The Cincinnati region is famous for fossils, and they did not escape the attention of young Charles Schuchert. At the age of 10 he obtained a copy of Volume I of the *Paleontology of Ohio* and found there the fossils of his own region described and illustrated. With this discovery his self-training in science began. A milestone in his advance was making the acquaintance of E. O. Ulrich, then curator of the collections of the Cincinnati Society of Natural History, who was equally as enthusiastic a fossil hunter as himself. After the loss of his business by fire, Schuchert became assistant to Ulrich in some work he was doing for the geological surveys of Illinois and Minnesota. Schuchert early specialized in brachiopods and in 1888 received from James Hall, State geologist of New York, an invitation to come to Albany to become Hall's assistant. While serving as assistant to Hall he became closely associated with John M. Clarke and Charles E. Beecher. All three were working on brachiopods and became life-time friends. In later years Clarke succeeded Hall as State geologist of New York and Schuchert succeeded Beecher at Yale University.

From New York, Schuchert was called in 1893 to the United States Geological Survey as assistant to C. D. Walcott. A year later when Walcott became director of the Survey, Schuchert transferred to the National Museum as assistant curator of invertebrate fossils.

His services at the National Museum continued until he was called to Yale in 1903. During this time he published, among many other important papers, his *Synopsis of American Fossil Brachiopoda*, which was one of his outstanding contributions.

It was at Yale and under the influence of his teaching experience that Schuchert developed the broader field of his life work, paleogeography. Heretofore he had written for specialists, but in his teaching he found it necessary to present his ideas to students. This led to the necessity for charts and maps, and the mapping of earlier lands and seas, begun



Science Service Washington, D.C.

CHARLES SCHUCHERT

at this time, continued throughout the remainder of his life. His contract at Yale appears not to have originally required actual class work with undergraduates. However, he had not been long at Yale until he felt the necessity of closer contact with students. Not having taught or even been a member of a college class, he began teaching with many misgivings and in later years gave interesting accounts of the difficulties he had to overcome in appearing before a class as a lecturer. He retired from active teaching at 67 but in later years accepted teaching appointments each for a short time at the University of Texas and the University of Arizona. Although primarily a researcher, his class-room duties undoubtedly enriched his experiences and broadened his vision.

Schuchert was a great reader and a striking characteristic was the assiduity with which he assembled and utilized, always with meticulous credit, the stratigraphic observations as they appeared in the literature. If any criticism at all can be made of his publications, it is on over generous acceptance, with appropriate credit, of the published results of his associates but with equal readiness to correct his own publications when corrections were found to be in order. He was author of more than 200 publications, and while his first love was paleontology, he is probably most widely known for his work in paleogeography. His first great contribution to this subject was his *Paleogeography of North America* published in 1910. After terminating his active duties as administrator and teacher, he continued his investigations, with emphasis on paleogeography, until the last days of his life. His most ambitious single publication, *Historical Geology of North America*, was undertaken after his retirement. Volume I, *Historical Geology of the Antillean-Caribbean Region*, was issued in 1935. At the time of his death, the publication of Volume II, *Stratigraphy of the Eastern and Central United States*, was practically complete, and the volume was distributed directly thereafter. The text and maps of Volume III, *Stratigraphy of Greater Acadia, Eastern and Central Arctic Canada, the Arctic Archipelago, and Greenland*, likewise were essentially finished. These three volumes, completed at the age of 84, round out a remarkable record of scientific achievement.

Schuchert's early life with its attending hardships made him particularly sympathetic with worthwhile students who were in need of financial help. His advice and guidance were an inspiration to his students, and he was responsible for, or shared in, the training of a notable group of investigators in the geologic sciences. In a peculiar sense Schuchert belongs to no one group or institution but to the geologic sciences as a whole. Beginning with an amateur's interest in geology, he terminated a long career as a master in the science.

E. H. Sellards

The University of Texas
Austin, Texas
April, 1943

FRANK SHACKLEFORD BOGGS, JR.
(1914–1942)

Frank Shackleford Boggs, Jr., was born on October 14, 1914, in San Francisco, California. He lost his life in an airplane crash in June, 1942.

Frank attended grade school in Stockton, California, and high school in Los Gatos, California, graduating in May, 1933. Entering the University of California at Berkeley in August, 1933, he graduated with a Bachelor of Arts degree in geology in August, 1938. He was a commendable student while at the university, having made excellent grades, and was a member of the Alpha Tau Omega social fraternity. During the summers of his college career he worked in the office of his father, F. S. Boggs, who was engaged in the real estate and insurance business. Frank became an associate member of the American Association of Petroleum Geologists in 1940.

Possessing an overpowering wanderlust, Frank, in 1937, made an extended tour through Japan, China, Siberia, and Continental Europe. In November, 1938, he entered the employ of the Shell Oil Company, Incorporated, at Houston, Texas, as a field geologist and from this date until May, 1940, was engaged in reconnaissance and detailed field work in South and East Texas.

Frank had two avocations in which he was deeply interested: aviation and radio. However, aviation was his major interest and having his own plane, Frank's leisure time was spent in flying and studying aviation. In May, 1940, he resigned his position with the Shell to continue his study of aviation. In order to develop his flying instinct, he also became a

gliding enthusiast, and cheated death once by "bailing out" of a glider when a wing collapsed at an altitude of 5,000 feet.

Although Frank left the field of petroleum geology to advance himself in the field of aviation, his true love was geology. His close associates knew him as a young man possessed of a vigorous imagination and his work was characterized by painstaking attention to detail. Frank loved to study geologic maps and visit areas of geologic interest. A person of exemplary habits, modest, unassuming, ambitious and very sincere, the geologic profession has been deprived of an individual of exceptional promise by his untimely death.

ROY R. MORSE

HOUSTON, TEXAS
April, 1943

JORGEN O. NOMLAND
(1885–1943)

The many friends and associates of Dr. Jorgen O. Nomland were deeply shocked and grieved to learn of his sudden death on May 7, 1943, the result of a heart attack while working in the garden of his home at Lafayette, California.

Dr. Nomland was born in Buxton, North Dakota, on August 24, 1885. His interest in the field of geology began at the University of North Dakota, where he majored in geology and mining. Upon his graduation in 1910 he accepted a teaching fellowship at the University of California, taking graduate work in the fields of geology and paleontology. Here he received his M.A. degree in 1915, his Ph.D. degree in 1916. As a result of his studies he published several papers, concerned chiefly with the stratigraphy and paleontology of the Coalinga area of central California.

Dr. Nomland—"Doc" as he was known to his many friends and associates—was at heart a scientist and viewed the world through the eyes of science. He was a student of geology and particularly interested in stratigraphy and paleontology. It was a real joy for "Doc" to find a new fossil locality and a pleasure to him to identify properly and describe some rare species. He was reserved by nature and was very studious; and his keen observation of animate as well as inanimate things, coupled with a quaint sense of humor, endeared him to those who knew him best.

In 1918 Dr. Nomland married Gladys Ayer, a girl of considerable scientific ability, who for years has carried on research work in anthropology at the University of California.

On August 1, 1916, Dr. Nomland began his career as geologist for the Standard Oil Company of California. His first 3 years were spent in geological field work in California and Mexico. In February, 1919, he was placed in charge of an important foreign geological expedition, and for four years carried on investigations in Central America and Panama. Following a trip to French Indo-China in 1923, he returned to the home office and was appointed assistant chief geologist in November, 1925. Then followed 17 years of foreign geological exploration in almost all of the petroliferous countries of the world. Outstanding among the many journeys which he made was his trip to Bahrein and Saudi Arabia. While in Arabia he visited Riyadh and Jedda and was guest of King Ibn Saud and the Crown Prince. He also made extended trips into the Philippines, Colombia, Venezuela, Cuba, Northwest India, and spent some time in the company's offices in London and The Hague.

In November, 1942, Dr. Nomland retired from active service with the Standard Oil Company of California. He had planned to "throw away his alarm clock," continue studies on some interesting scientific problems, and "work hard" on his ranch at Lafayette, California. It is to be regretted that the pleasant years of retirement to which he looked forward should have been so abruptly terminated.

G. C. GESTER

SAN FRANCISCO, CALIFORNIA
May, 1943

WILLIAM McCORMICK REID
(1911–1943)

"Man with his burning soul
Has but an hour of breath
To build a ship of truth
In which his soul may sail—
Sail on the sea of death,
For death takes toll
Of beauty, courage, youth,
Of all but truth. . . ."

William McCormick Reid died in Edmonton, Canada, on May 11, 1943. Death came suddenly and without warning; he had been stricken only a few days before at Norman Wells, 1,000 miles farther north, where, as a field geologist, he had been engaged on the United States Army's project to develop oil in the Far North.

William Reid was born in Birmingham, Alabama, August 30, 1911, the son of Robert Cornelius Reid and Katherine Brown Reid. He attended elementary school at Hattiesburg, Mississippi, and graduated from high school at Birmingham, Alabama. He studied for 2 years at the University of Alabama, but his geological training was obtained at the University of Kentucky which granted him a bachelor's degree from the School of Engineering in 1935. He went to work immediately in the geological department of the Humble Oil and Refining Company at Houston, Texas, and in due time was promoted to the position of geologist. He became a member of the Association in May, 1939.

He was married in September, 1940, to my daughter, Nancy Pratt Reid, and they have two infant sons, William, Jr., and Edward Brown Reid.

He was still a member of Humble's staff at the time of his death, but, determined to participate more directly in the common struggle which war has imposed on us and denied admission to the Army Air Corps (he was a licensed airplane pilot), he had secured extended leave and had volunteered for work as a geologist on the Army's Arctic project.

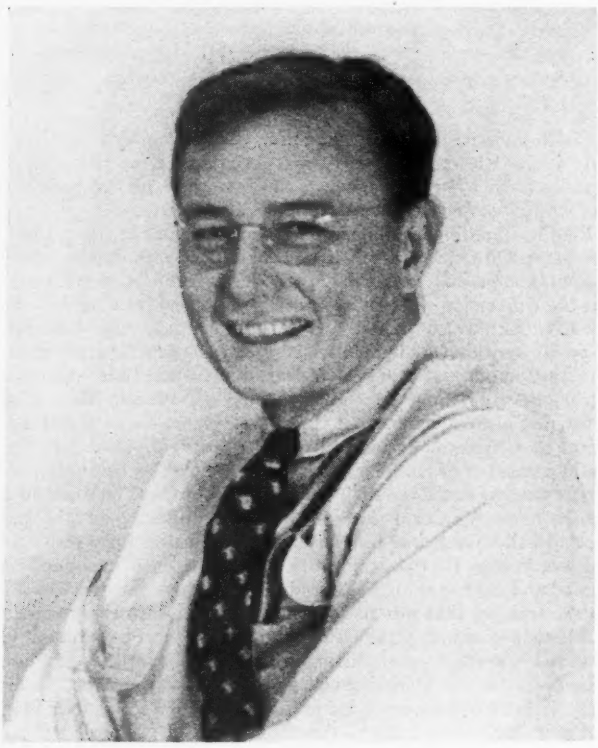
Bill Reid was young. His scientific work had not ripened into publication. Yet his qualities of mind and character distinguish him beyond his years. In school he undertook purposefully the training that was to gain him admission into the professional world of science. His attitude of mind, stamped by an ethical concept of human labor and the relationship of fellow workers, soon distinguished him. His interests embraced a variety of extra-curricular activities including college athletics in which he excelled. He was a member of the Sigma Chi fraternity. He impressed himself on his friends in the faculty. Dr. Arthur Crane McFarlan, head of the department of geology at the University of Kentucky, became at once his mentor and his friend, allotting to him certain special duties which identified the young man in his own mind with the work of the university, an association which he cherished through the rest of his life.

The attributes of character which had marked him in college persisted throughout his career. His brief professional life bore their fixed imprint. His was a mature dignity, the expression, not of an awareness of self, but of his sense of the dignity of others. He was considerate far beyond mere courtesy. To the driller on the "grave-yard tower," or to the top executive at a "board-room conference" he showed the same consideration. He respected his fellow man. It was what he "owed" to the other fellow.

Animated by an intellectual integrity, at once rigorous and simple, his duty was to him ever crystal-clear. Duty kept him on the derrick floor 24 hours at a stretch when a well was "coring for the sand." Duty kept him in the field in the Arctic until, with death already upon him, he finally struggled back to camp and, seeking out the doctor, in shy apology confessed, "I guess I just can't take it, doctor."

What makes a scientist? In a world at war, all but submerged in a chaos of hatreds and destruction, we anxiously ponder the training our universities shall prescribe for the

scientists of the future. How shall we inspire and nourish the mental integrity, the steadfast humility, and the intellectual courage which, along with industry, orderliness, and curiosity mark the occasional great ones among us? The problem perplexes, and when,



recognizing these rare qualities in one of our fellows, we see them wither before they blossom, we turn in even greater perplexity to Science, itself, to ask:

> "Where wert thou, mighty Mother, when he lay,
> When thy son lay, pierced by the shaft which flies
> In darkness?"

WALLACE E. PRATT

NEW YORK, N. Y.
June 7, 1943

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 27, NO. 7 (JULY, 1943), PP. 1033-1038

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

L. C. SNIDER, president of the Association in 1941, now a member of the geological faculty of the University of Texas, at Austin, has been retained by the Seaboard Oil Company, of Dallas, Texas, for the summer months.

The Tulsa Geological Study Group, of which L. MURRAY NEUMANN of the Carter Oil Company is president, has awarded a scholarship to NATHAN ALTSHULER, a graduate of the Tulsa High School, in order that he may attend the Princeton University summer camp in geology near Cody, Wyoming.

GEORGE H. GAUL has been transferred from the Sinclair Prairie Oil Company to the Sinclair Wyoming Oil Company at Lander, Wyoming.

G. H. CROWL, who has been instructor in geology at Vanderbilt University, Nashville, Tennessee, for the past year, has accepted a similar position at Hamilton College, Clinton, New York.

BEN B. COX, of the Socony Vacuum Oil Company, New York, is a major in the Air Corps at Eglin Field, Florida.

H. L. SCOTT is division representative in charge of the oil exploration program of the Northern Ordnance, Inc., and is now located in the Philtower Building, Tulsa, Oklahoma.

A. I. LEVORSEN is associated with the Northern Ordnance, Inc., in a consulting capacity.

VICTOR OPPENHEIM recently returned to Bogota, Colombia, after a trip of a year through the South American republics for the Socony Vacuum Oil Company. He was recently elected to membership in the Colombian Academy of Science, the Geographical Society of La Paz (Bolivia), and the Geological Society of Peru.

WILLIAM A. WALDSCHMIDT, mining and geological engineer, is at 4840 Tennyson Street, Denver, Colorado.

HUBERT G. SCHENCK has been granted an indefinite leave of absence from Stanford University in order to accept a commission as major in the army.

New officers of the Corpus Christi Geological Society, Corpus Christi, Texas, are: president, FRITH C. OWENS, consulting geologist; vice-president, E. D. PRESSLER, Humble Oil and Refining Company; secretary-treasurer, BRUCE SCRAFFORD, consulting geologist, Driscoll Building. Luncheons are held every Wednesday in the Petroleum Room of the Plaza Hotel at 12:05 P.M.

The West Texas Geological Society has awarded a geological "field scholarship" to WILLIAM TERRY ELKIN of the Junior class at Midland High School. This award consists of tuition and expenses for the summer field course at The University of Princeton's geological summer camp in the Bighorn Basin near Cody, Wyoming, from July 5 to August 14, 1943. The purpose of the award is to encourage interest among high-school students in exploratory geology as a possible professional career. Elkin was chosen by the West Texas Geological Society merit award committee from among members of the Junior class on the basis of his scholastic record and personal qualifications for field work.

AMERICAN MUSEUM OF NATURAL HISTORY
DEPARTMENT OF MICROPALEONTOLOGY

The Department of Micropaleontology in the American Museum of Natural History was established by action of the Trustees, June 20, 1940, to continue, on a permanent basis, the work initiated by its special project on Foraminifera. Specifically, the objectives of the Department are:

I. To maintain a service for subscribing members which will include
   1. Publication of supplementary material designed to keep the members' sets of the Catalogue of Foraminifera up to date
   2. Maintenance of a general clearing-house for literature and specimens
   3. Maintenance of a depository of types and faunas
   4. Services of artists and draftsmen

II. To conduct research on
   1. Special problems presented by subscribing members
   2. Academic problems in micropaleontology

Since the principal aim of the Department is to establish and maintain a service, the Trustees ruled that it must be, at least in part, self-supporting. On the other hand, the chief purpose of the Museum is to foster research and from this standpoint the administration has been free to give the Department extensive support. This includes housing, equipment, maintenance, and service. These constitute a considerable part of the expense of operating the Department.

In the normal course of events, the income from subscriptions would have been sufficient to meet the remaining budgetary requirements. However, the impact of the war has practically eliminated all foreign subscriptions and many individual domestic ones. The present membership consists almost solely of oil companies and educational institutions. The income from these memberships is not sufficient to meet the requirements of the Department. To continue to offer even the basic service of keeping the Catalogue up to date, additional funds must be found to supplement the income from subscriptions and the contributions made by the Museum.

Initial membership.—Membership is secured through application. Subscribers apply first for Initial Membership which extends from the date of acceptance to January 1, or to July 1 if the application is accepted after January 1. Initial Members in the Section of Foraminifera receive the 30,000-page Catalogue of Foraminifera as the first benefit of membership. Other benefits are the same as those listed under Continuing Membership except that they are available for a shorter period of time and the increment of genera and species is correspondingly limited. The Initial Membership fee is $100 and is due when the application for membership has been accepted. Upon the expiration of Initial Membership subscribers are entitled to continue their membership under one of the following plans.

Continuing membership.—One of the most basic services offered is that of keeping the Catalogue up to date. Supplementary material for new genera and species will be issued twice yearly. Continuing Members are entitled to a maximum annual increment of 500 units.

Continuing Members will also be entitled to access to the source material in the archives, either by visit or correspondence. The annual dues for this type of membership are $25 and are payable at the beginning of the year (January 1 or July 1) for which membership is subscribed.

Active membership.—Although the Catalogue is a complete unit within itself, the field of its usefulness can be extended enormously by access to the source material in the Department. Active Members will be entitled to full access to this material as well as to the research and editorial services of the entire Department, at special low rates.

Continuation is also included and entitles the Active Member to an unlimited annual increment of units. The annual dues for this class of membership are $100, payable at the beginning of the year (January 1 or July 1) for which membership is subscribed. This class of membership is especially designed to meet the needs of oil companies.

Further information may be obtained from Brooks F. Ellis, curator, Department of Micropaleontology, American Museum of Natural History, Central Park West at 47 Street, New York, N. Y.

APPLICATION OF GEOLOGY TO THE PRINCIPLES OF WAR

The following is an abstract of a paper by CHARLES E. ERDMANN which will be published in an early number of the *Bulletin* of the Geological Society of America. Copies of the complete paper may be obtained from H. R. Aldrich, Secretary, Geological Society of America, 419 West 117th Street, New York, N. Y.

This article surveys the employment of geology in war with special reference to its tactical application. Approaching the subject theoretically, from a military rather than an academic viewpoint, the first problem examined is whether our present undistinguished use of geology in war results from some inapplicability inherent in the science itself, or whether a more rational analysis will not disclose wider fields of application by recognition of hitherto unsuspected correlations with the principles of war. After preliminary definitions of war, the principles of war, geology and military geology, the development of military geology is outlined to show what aspects have been most useful and the phase of warfare to which they are best adapted. This reveals that there has been but little actual tactical application of geology in mobile warfare or a war of maneuver, and that its employment has not been worked out satisfactorily in the United States Army, although it has been developed to some extent by the Germans. Hence, in our current engagements geology seems not to be utilized fully because of the erroneous belief that it can not be applied with sufficient rapidity to keep pace with the course of modern combat. In order to bring the soldier and the geologists into mutual understanding, military and scientific thought are compared and shown to follow substantially the same outline. Then the terrain is considered from the viewpoint of army doctrine and geology, and emerges as the common denominator of geology and war. With terrain as the connecting link geology can be correlated with the principles of war. When military leaders are convinced that these correlations are valid and contribute to the strength of the principles of war, more widespread applications of geology to war will follow, and geology will rightfully take its place among the "front-line" sciences. Other conclusions are that, as the principles of war are immutable, and do not vary with change of weapons or tempo of combat, it follows that geology can keep pace with modern war in its most fluid tactical phases. Geology makes its chief contribution to war through the principles of Mass (Superiority) and Economy of Force, the fundamental law of war; but the principles of Movement (Mobility), Surprise, Security, and Simplicity are also strengthened through its application. The total effect of the application of geology to these principles is superior information—upon which the possibility of success is principally dependent. Some suggestions are made regarding the geologic training and military qualifications of the modern military geologist. Finally, when all other things are equal, victory will come to him who makes best use of the ground.

PROGRESS REPORT OF DISTINGUISHED LECTURE COMMITTEE

JOHN L. FERGUSON, chairman of the distinguished lecture committee, reports as follows. The activities of the distinguished lecture committee for the year 1942–43 were concluded by the lecture tours of JOHN L. RICH of the University of Cincinnati and PAUL D. KRYNINE of the Pennsylvania State College.

Dr. Rich delivered a superbly illustrated address on "Problems in South American Geology as Suggested by an Aerial Traverse" before the following geological groups.

April	5	Tulsa Geological Society at Tulsa
	6	Oklahoma City and Shawnee Geological societies at Oklahoma City
	10	Geology Department, Texas Technological College, Lubbock
	12	West Texas Geological Society at Midland
	13	Dallas Petroleum Geologists at Dallas
	14	South Texas Geological Society at San Antonio
	15	Houston Geological Society at Houston
	15	South Louisiana Geological Society at Lake Charles
	16	Mississippi Geological Society at Jackson
	17	Illinois and Indiana-Kentucky Geological societies at Mt. Vernon, Illinois

Dr. Krynine concluded the season's tours with an extensive trip to the Pacific Coast, during which he addressed and gave demonstrations before seventeen geological groups concerning his new classification of sedimentary deposits. His subject was "Diastrophism and the Evolution of Sedimentary Rocks." The following societies sponsored this tour and participated in it.

April	22–24	Michigan Geological Society at Lansing
	26–27	Indiana-Kentucky and Illinois Geological societies at Evansville, Indiana
	29–30	Kansas Geological Society at Wichita
May	1–5	Tulsa Geological Society
	6–7	Oklahoma City and Shawnee Geological societies at Oklahoma City.
	8–9	Ardmore Geological Society
	10–12	Fort Worth Geological Society
	13–15	North Texas Geological Society at Wichita Falls
	17–19	South Texas Geological Society at San Antonio
	20–22	Corpus Christi Geological Society
	24–25	East Texas Geological Society at Tyler
	27–29	West Texas Geological Society at Midland
May	31–June 3	Pacific Section A.A.P.G. at Los Angeles and Pasadena
June	4–5	San Joaquin Geological Society at Bakersfield

The committee is making arrangements for the season of 1943–44, and hopes it will be able to bring before the affiliated societies as able and instructive a group of speakers as the seven authorities who appeared this year.

RAY E. MORGAN has resigned his position at Wisconsin Institute to accept a position on the geology teaching staff at Purdue University, where he will be associated with professor F. L. SERVISS.

CARL B. IRWIN is in Kansas City as supervisor of inspection and shipping of Navy petroleum.

J. REX MCGEHEE has been transferred from Centralia, Illinois, to Tulsa, Oklahoma, with the Shell Oil Company, Inc.

E. RUSSELL LLOYD, consulting geologist at Midland, Texas, has given 750 volumes of geological publications to the Midland County Public Library.

JOSEPH W. LANG is assistant geologist in the Ground-Water Division of the United States Geological Survey, Pecos, Texas.

A. RODGER DENISON visited with individual members and groups of members of the Association on a recent trip east that included Pittsburgh, Washington, D. C., and New

York City. At New York a group called together by FRED B. ELY, outgoing district representative, in the absence of representative LEWIS G. WEEKS, listened to president Denison's discussion of the manpower situation, on June 22; and at Pittsburgh, district representative M. GORDON GULLEY arranged a meeting for the discussion of similar current problems and other Association affairs, on June 24.

JOSEPH M. DAWSON, consulting geologist of San Antonio, Texas, is representing the Hunt Oil Company of Shreveport, Louisiana, at Mt. Vernon, Illinois. GRADY KIRBY, also of San Antonio, is with the Hunt Company in Illinois.

LESLIE M. CLARK, of the Shell Oil Company, Inc., has moved from Centralia, Illinois, to the Shell Oil Company of Canada, Ltd., Bank of Toronto Building, Calgary, Canada.

CLIFTON S. CORBETT, of the Socony-Vacuum Oil Company, has moved from New York to 905 Lancaster Building, Calgary, Canada.

JAMES F. GIBBS, of Wichita Falls, Texas, formerly with the Panhandle Refining Company, is geologist with the Standard Oil Company of Texas.

PHILLIP D. HELMIG, JR., of San Antonio, Texas, is a captain in the Army, somewhere is Australia.

GEORGE A. MUSSELMAN, of the Carter Oil Company, Tulsa, has been appointed district geologist of the Mississippi-Alabama district, with offices in Jackson, Mississippi.

OTTO FISCHER, of Charleston, West Virginia, a charter member of the Association, died recently at the age of 66 years. He was for many years with the Owens, Libbey-Owens Gas Department. He was the first president of the Appalachian Geological Society.

GEORGE CURTIS MARTIN, geologist and executive secretary of the United States Board on Geographical Names, died at Washington, D. C., June 22, at the age of 66 years.

THOMAS W. LEACH, consulting geologist and operator of Tulsa, Oklahoma, and Bismarck, North Dakota, is a captain in the Coast Artillery (Anti-Aircraft).

The Alberta Society of Petroleum Geologists has elected the following officers: president, W. C. HOWELLS, McColl-Frontenac Oil Company, Ltd.; vice-president, J. M. KIRBY, Dominion Oil Company, Ltd.; business manager, D. B. LAYER, McColl-Frontenac Oil Company, Ltd.; secretary-treasurer, J. D. WEIR, Dominion Oil Company, Ltd. All have offices in the Lancaster Building, Calgary, Alberta, Canada.

A. W. POWERS, father of SIDNEY POWERS, in whose memory the Association is raising a fund for a memorial award, passed away, May 22, at Troy, New York and was buried in the family plot. Mrs. A. W. Powers, of Troy, survives.

H. R. WOFFORD, JR., of San Antonio, Texas, is with the International Petroleum Company, Ltd., Guayaquil, Ecuador.

HORACE R. BLANK, of the Hydrologic Division of the U. S. Soil Conservation Service, may be addressed at the department of geology of Southwestern University, Georgetown, Texas.

PAUL H. PRICE, State geologist of West Virginia, has received a commission as Major, Spec. Res., as a natural resource specialist through the Provost Marshal General's Department of Military Government, effective June 26.

Captain HALL TAYLOR is on duty with the Army in the Hawaiian Islands. He reports seeing interesting geology but no time to study it.

ROY A. REYNOLDS, consulting geologist of Fort Worth, Texas, died on June 19.

E. O. BUCK, recently District 3 director of production in the Petroleum Administration for War, is now southern manager for the Rowan Drilling Company, Houston, Texas.

GERALD C. ROBERTS, formerly with the Seaboard Oil Company at Corpus Christi, is with the Sinclair Prairie Oil Company, Midland, Texas.

R. E. SPRATT, of the United States Geological Survey, has been transferred from Denver, Colorado, to Room 3229, North Interior Building, Washington, D. C.

EUGENE B. WAGGONER is with the Superior Oil Company, Denver, Colorado.

LEROY FISH, recently with The Texas Company at Corsicana, Texas, is with Petroleos Mexicanos, Dept. de Exploracionès, Mexico, D.F.

CARL W. HUBMAN, recently with the Colombian Petroleum Company at Cucuta, Colombia, has enlisted in the Corps of Engineers. His forwarding address is Box 122, Boulder, Colorado.

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Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every Thursday, at 12:00 noon, Skirvin Hotel Coffee Shop.

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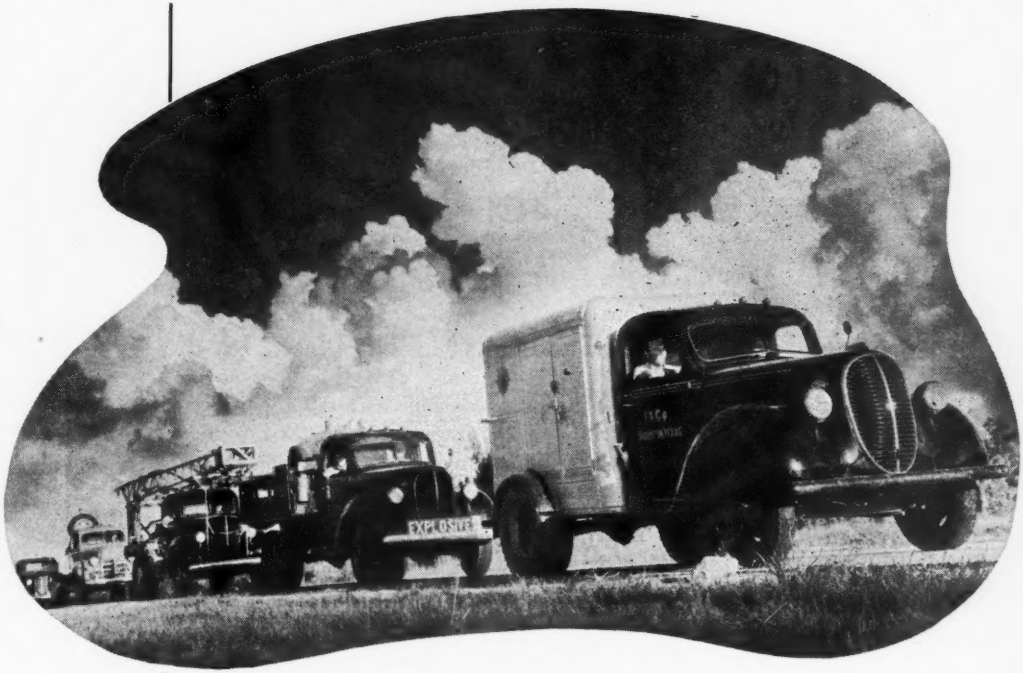

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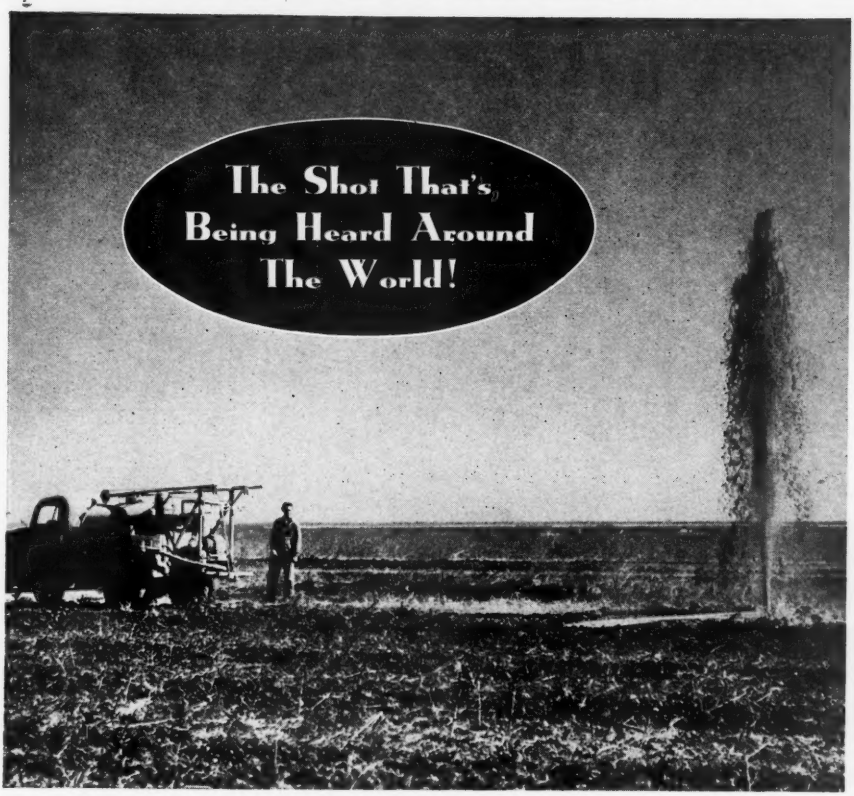

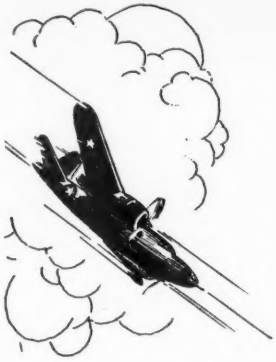

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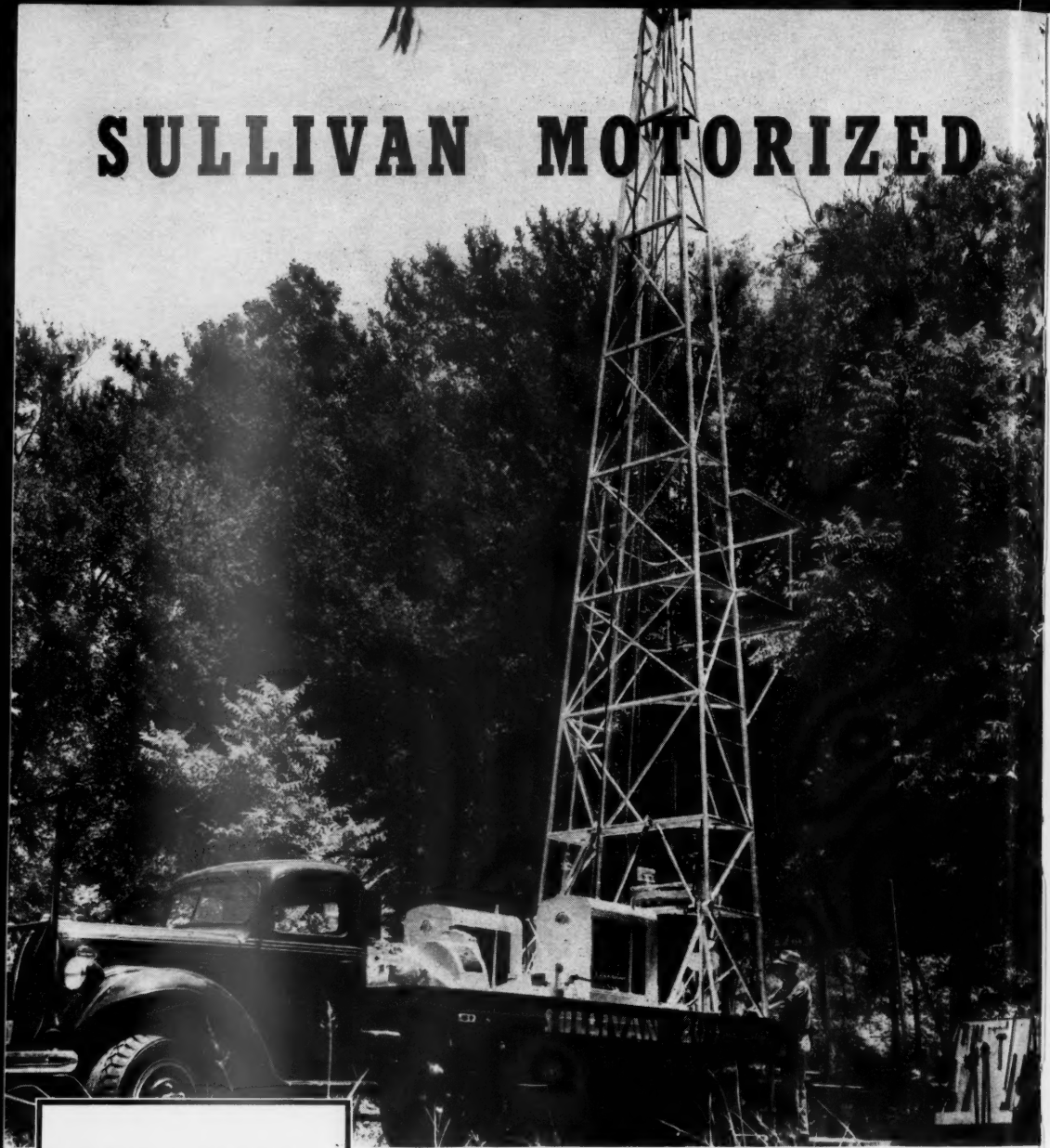

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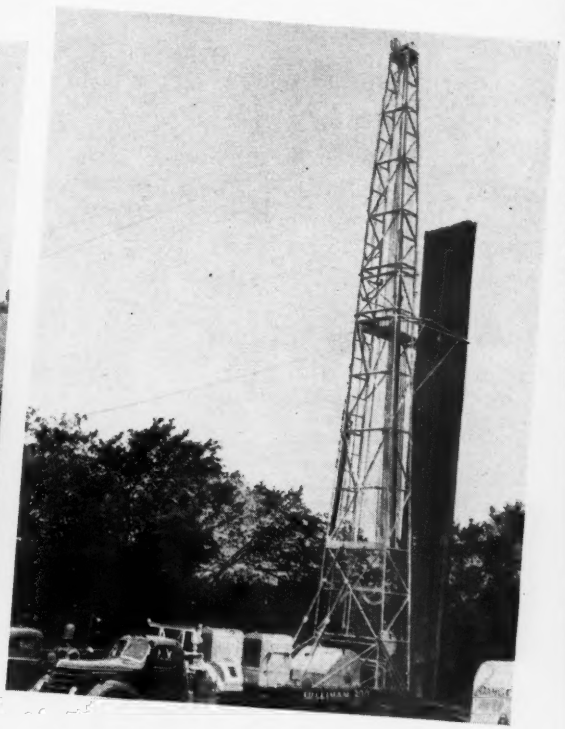

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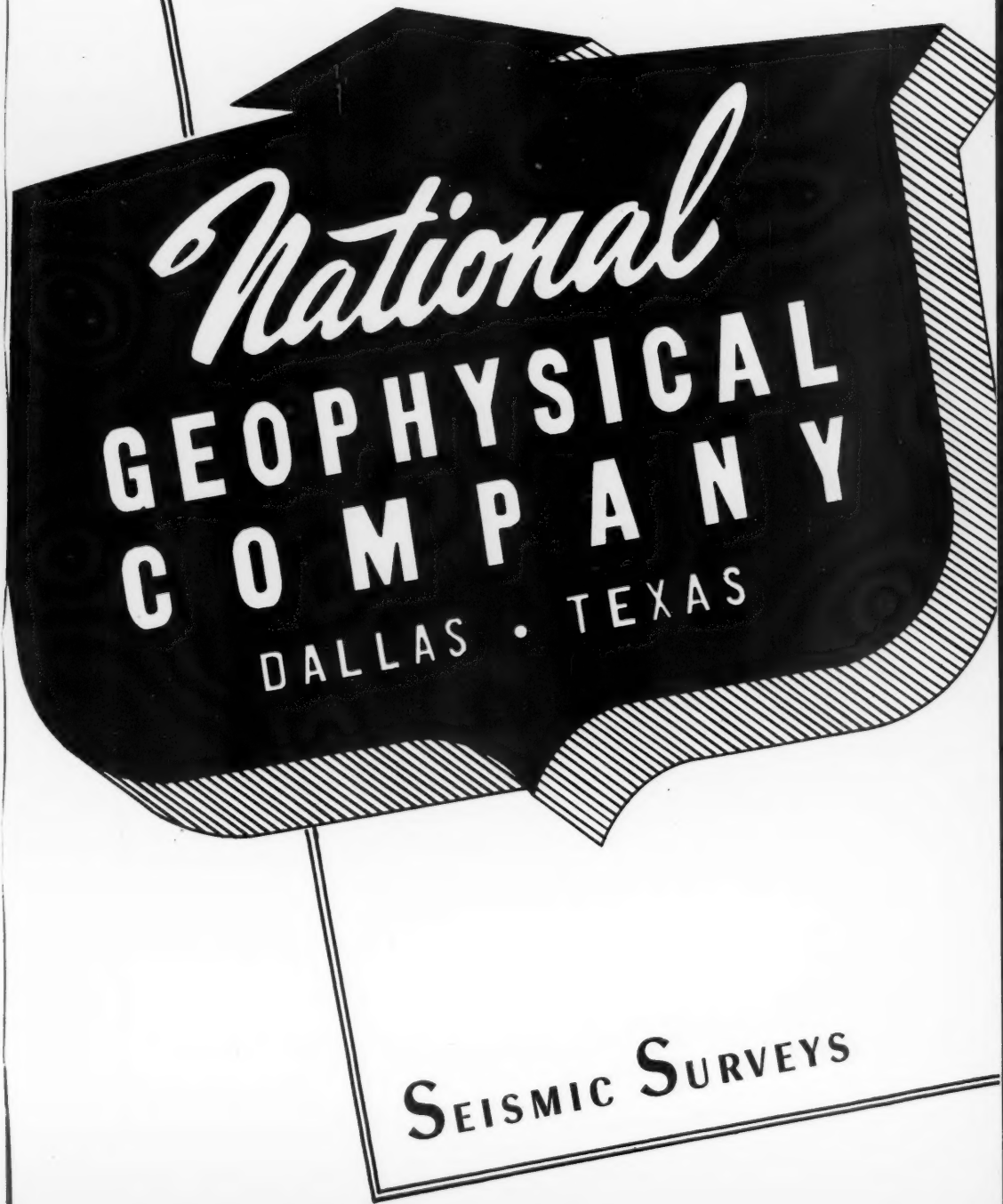
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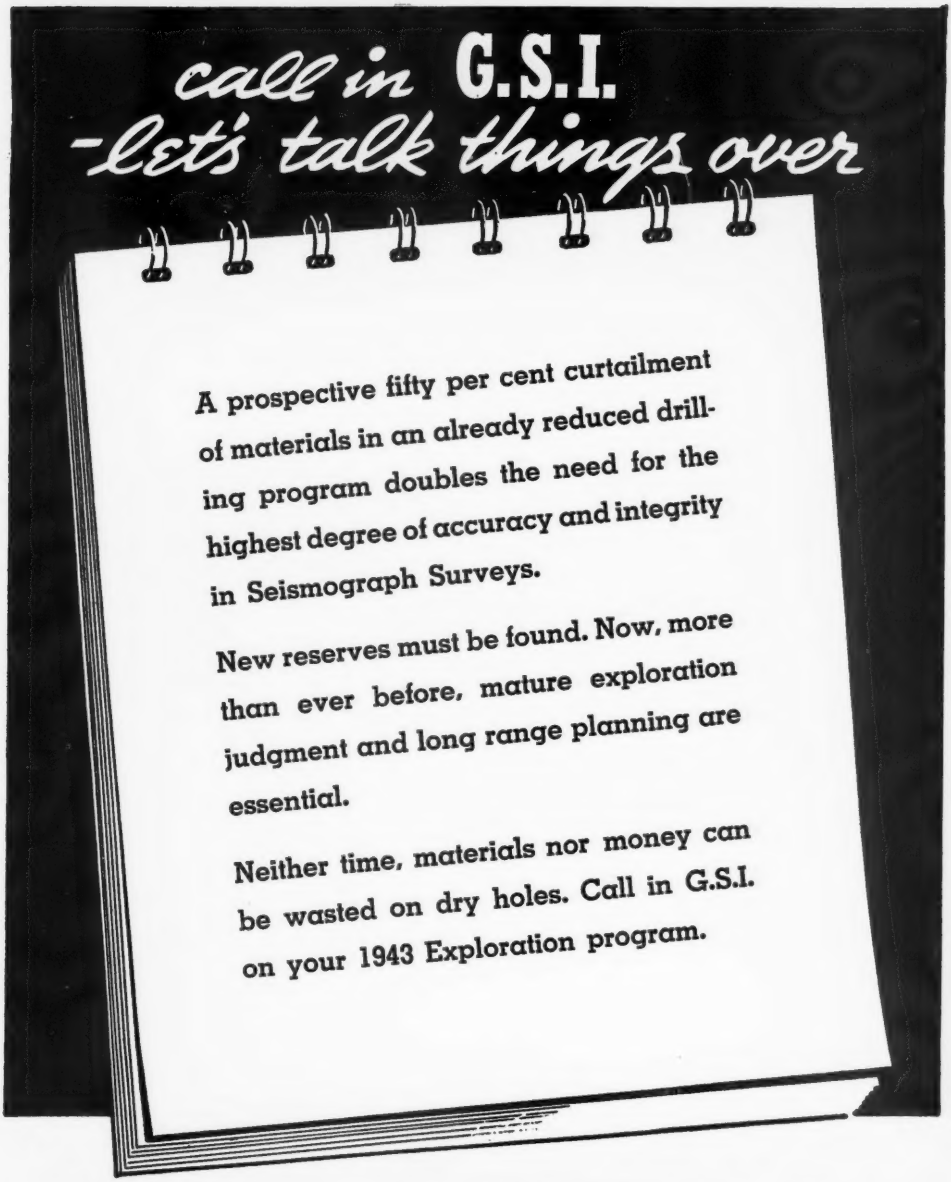
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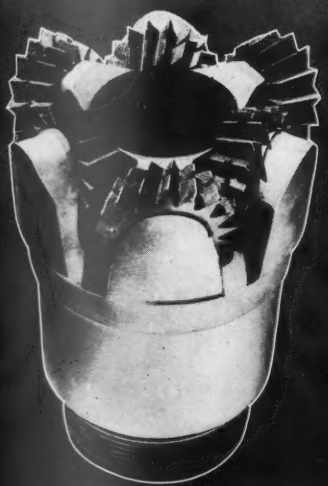

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